The Consultative Committee for Space Data Systems

Draft Recommendation for Space Data System Practices

IP OVER CCSDS SPACE LINKS

DRAFT RECOMMENDED PRACTICE

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DOCUMENT CONTROL

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PREFACE

This document is a draft CCSDS Recommended Practice. Its 'Red Book' status indicates that the CCSDS believes the document to be technically mature and has released it for formal review by appropriate technical organizations. As such, its technical contents are not stable, and several iterations of it may occur in response to comments received during the review process.

Implementers are cautioned **not** to fabricate any final equipment in accordance with this document's technical content.

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to establish a CCSDS Recommended Practice specification for the implementation of IP over CCSDS Space Data Link Layer protocols in both spacecraft and ground systems by the Agencies participating in the CCSDS.

1.2 SCOPE

This document addresses the following three recommended methods for transferring IP datagrams over CCSDS space links:

a) placed directly into CCSDS Frames;

b) utilizing the CCSDS Encapsulation Service;

c) utilizing a user-provided serial-stream encapsulation.

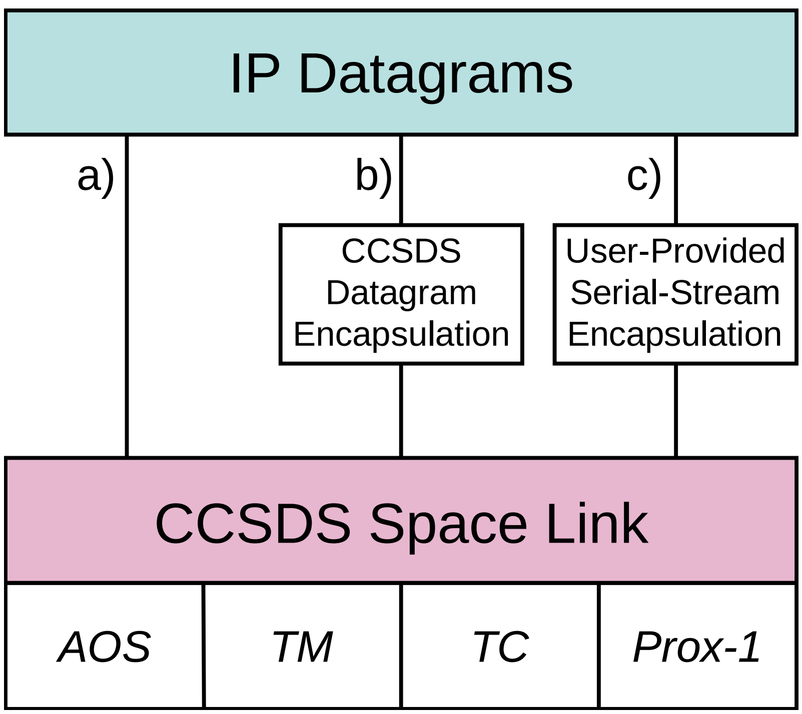

Figure 1-1: Scope of IP over CCSDS Data Links

1.3 CONVENTIONS AND DEFINITIONS

1.3.1 DEFINITIONS

1.3.1.1 Definitions from the Open Systems Interconnection (OSI) Basic Reference Model

This document makes use of a number of terms defined in reference [1]. The use of those terms in this document shall be understood in a generic sense; i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are:

a) blocking;

b) connection;

c) Data Link Layer;

d) entity;

e) flow control;

f) protocol data unit;

g) real system;

h) segmenting;

i) service;

j) Service Access Point (SAP);

k) SAP address;

l) service data unit.

1.3.1.2 Definitions from OSI Service Definition Conventions

This document makes use of a number of terms defined in reference [2]. The use of those terms in this document shall be understood in a generic sense; i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are:

a) confirmation;

b) indication;

c) primitive;

d) request;

e) response;

f) service provider;

g) service user.

1.3.1.3 Terms Defined in This Recommended Practice

For the purposes of this document, the following definitions also apply. Many other terms that pertain to specific items are defined in the appropriate sections.

asynchronous: not *synchronous* (see below).

delimited: having a known (and finite) length; applies to data in the context of data handling.

Mission Phase: a period of a mission during which specified communications characteristics are fixed. The transition between two consecutive Mission Phases may cause an interruption of the communications services.

periodic: of or pertaining to a sequence of events in which each event occurs at a fixed time interval (within specified tolerance) after the previous event in the sequence.

Physical Channel: a stream of bits transferred over a space link in a single direction.

space link: a communications link between a spacecraft and its associated ground system or between two spacecraft. A space link consists of one or more Physical Channels in one or both directions.

synchronous: of or pertaining to a sequence of events occurring in a fixed time relationship (within specified tolerance) to another sequence of events. Note that ‘synchronous’ does not necessarily imply ‘periodic’ or ‘constant rate’.

1.3.2 NOMENCLATURE

The following conventions apply throughout this document:

a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;

b) the word ‘should’ implies an optional, but desirable, specification;

c) the word ‘may’ implies an optional specification;

d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

1.3.3 CONVENTIONS

In this document, the following convention is used to identify each bit in an *N*-bit field. The first bit in the field to be transmitted (i.e., the most left justified when drawing a figure) is defined to be 'Bit 0'; the following bit is defined to be 'Bit 1' and so on up to 'Bit *N*–1'. When the field is used to express a binary value (such as a counter), the Most Significant Bit (MSB) shall be the first transmitted bit of the field, i.e., 'Bit 0' (see figure 1-2).

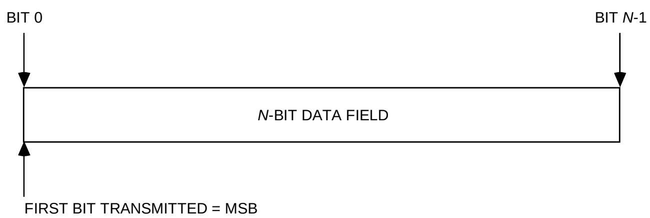

Figure 1-2: Bit Numbering Convention

In accordance with standard data-communications practice, data fields are often grouped into eight-bit 'words' which conform to the above convention. Throughout this Recommendation, such an eight-bit word is called an 'octet'.

The numbering for octets within a data structure starts with zero. By CCSDS convention, all 'spare' bits shall be permanently set to '0'.

1.4 REFERENCE DOCUMENTS

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommended Practice. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommended Practice are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Documents.

[1] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. International Standard, ISO/IEC 7498-1. 2nd ed. Geneva: ISO, 1994.

[2] *Information Technology—Open Systems Interconnection—Basic Reference Model—Conventions for the Definition of OSI Services*. International Standard, ISO/IEC 10731:1994. Geneva: ISO, 1994.

[3] *AOS Space Data Link Protocol*. Recommendation for Space Data System Standards, CCSDS 732.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, July 2006.

[4] *TM Space Data Link Protocol*. Recommendation for Space Data System Standards, CCSDS 132.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.

[5] *TC Space Data Link Protocol*. Recommendation for Space Data System Standards, CCSDS 232.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.

[6] *Proximity-1 Space Link Protocol—Data Link Layer*. Recommendation for Space Data System Standards, CCSDS 211.0-B-4. Blue Book. Issue 4. Washington, D.C.: CCSDS, July 2006.

[7] *Encapsulation Service*. Recommendation for Space Data System Standards, CCSDS 133.1-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, June 2006.

[8] *Space Link Identifiers*. Recommendation for Space Data System Standards, CCSDS 135.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, November 2005.

[9] *Communications Operation Procedure-1*. Recommendation for Space Data System Standards, CCSDS 232.1-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.

NOTE – Informative references are provided in annex F.

2 OVERVIEW OF TRANSFERRING IP DATAGRAMS OVER CCSDS LINKS

2.1 GENERAL

This section describes the recommend options for transferring IPv4 and IPv6 datagrams over CCSDS Space data link protocols: TC, TM, AOS, and Proximity-1. (See figure 2-1 below.)

Option 1: Transfer exclusively IPv4 datagrams within one or more CCSDS Space Data Link frames or multiplex them with other CCSDS recognized packets. This option uses CCSDS AOS Virtual Channel Packet (VCP), TC VCP, or TC Multiplexer Access Point (MAP) Packet (MAPP) transfer service.

Option 2: Transfer IPv4 datagrams as a serial octet-aligned stream within CCSDS Space Data Link frames. This option uses CCSDS AOS Virtual Channel Access (VCA) or TC MAP Access (MAPA) transfer service.

Option 3: Transfer IPv4 datagrams by encapsulating them,[1] one for one, within a CCSDS Encapsulation Packet. Transfer the Encapsulation Packet directly within one or more CCSDS Space Data Link frames. This option uses CCSDS Encapsulation (ENCAP) Service.

Option 4: Transfer exclusively IPv6 datagrams or multiplex them with other CCSDS recognized packets. This option is identical to Option 3, except that IPv6 datagrams are used.

Option 5: Transfer IPv6 datagrams as a serial octet-aligned stream by encapsulating them, one for one, within a CCSDS Encapsulation Packet. Transfer the Encapsulation Packet directly within one or more CCSDS Space Data Link frames. This option uses CCSDS Encapsulation (ENCAP) Service.

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[1] This option provides a migration path for future use of IPv6 datagrams.

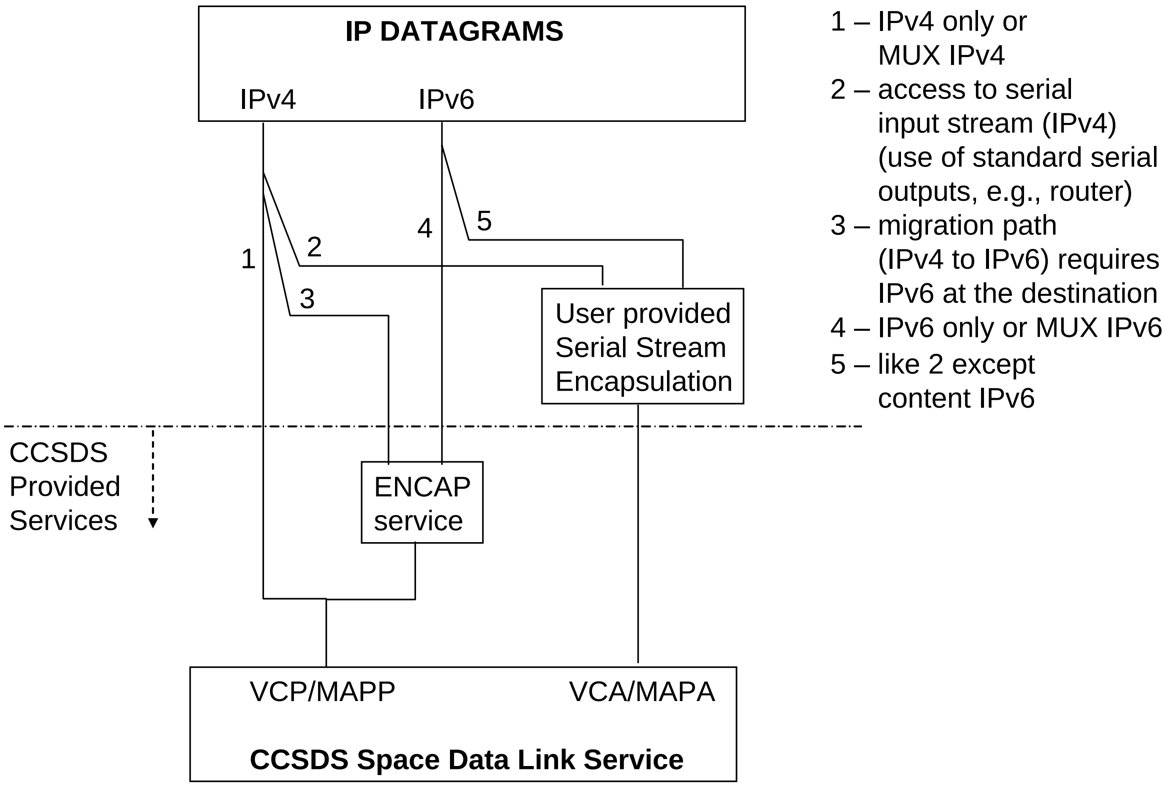


Figure 2-1: Recommended Options for Transferring IP over CCSDS Data Links

2.2 SERVICE INTERFACE

2.2.1 GENERAL

Figure 2-2 describes the interface between the service user, who accesses the transfer service at a Service Access Point (SAP), and the service provider, who performs the service by transferring the data unit across the space link. The user has two options for transferring IP datagrams over CCSDS links: a) provide an IP datagram and its associated link layer routing information (i.e., GVCID or GMAP ID) upon input to the Packet SAP or b) provide an octet-aligned data stream composed of IP datagrams along with their associated link layer routing information to the Octet Stream SAP. Link layer addressing is explained in terms of the hierarchy of link layer identifiers (e.g., GVCID) and channels shown in figure 2-3. A complete description of each of the CCSDS IP transfer services is provided in section 4, Service Primitives.

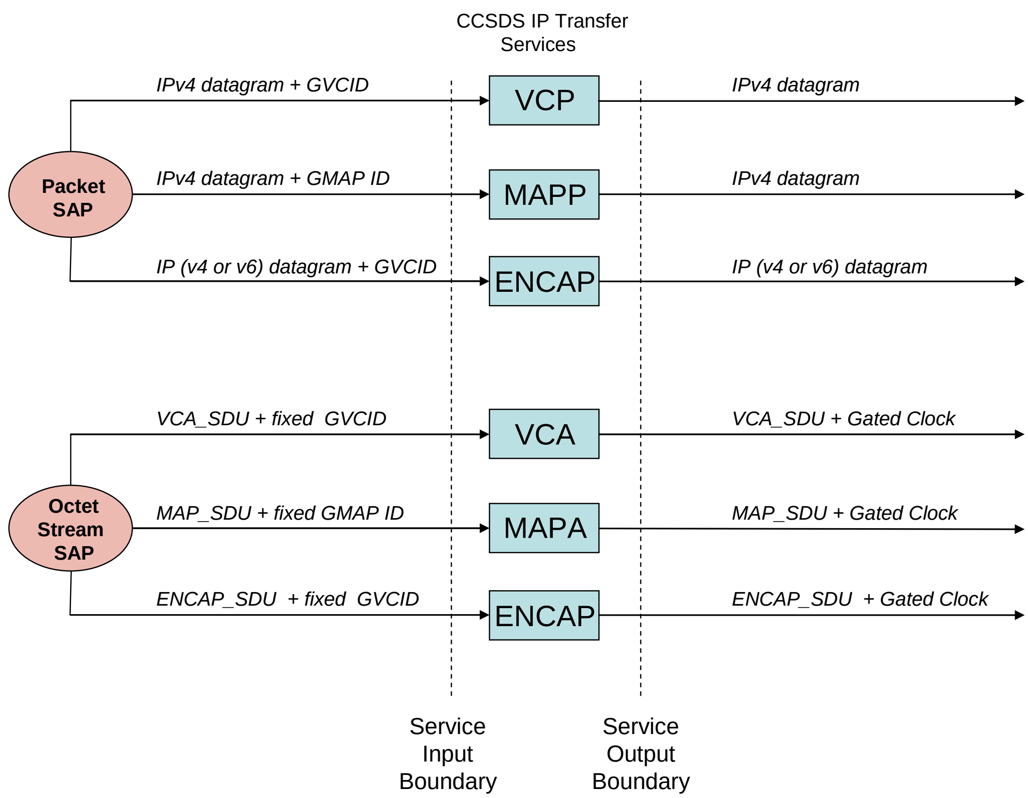


Figure 2-2: CCSDS IP Transfer Services Context Diagram

In order to transfer data units, e.g., either IP datagrams or octet streams (containing IP datagrams), the service user provides the appropriate link layer address of the data unit upon input to the service provider. For VCP, VCA, and ENCAP data transfer services, the user supplies the Global Virtual Channel ID (GVCID). The GVCID is a concatenation of the Transfer Frame Version Number (TFVN), Spacecraft ID (SCID), and Virtual Channel ID (VCID)[1] fields within the transfer frame header of a CCSDS link layer protocol. By specifying the GVCID, the user assigns the contents of the frame to a specific frame version number (TFVN), to or from a specific spacecraft (SCID), over a specific VCID. For MAPP and MAPA transfer services, the user supplies the Global MAP ID or GMAP ID. The GMAP ID is a concatenation of the Master Channel ID, VCID, and the Map ID. The Map ID provides an additional level of multiplexing MAP Channels over a given virtual channel principally for handling the segmentation and reassembly of datagrams larger than the maximum transmission unit of the transfer frame data field. Note that MAP channels are supported only by the TC Space Data Link Protocol. (See figure 2-3.)

[1] Proximity-1 uses Port-IDs in place of Virtual Channel IDs.

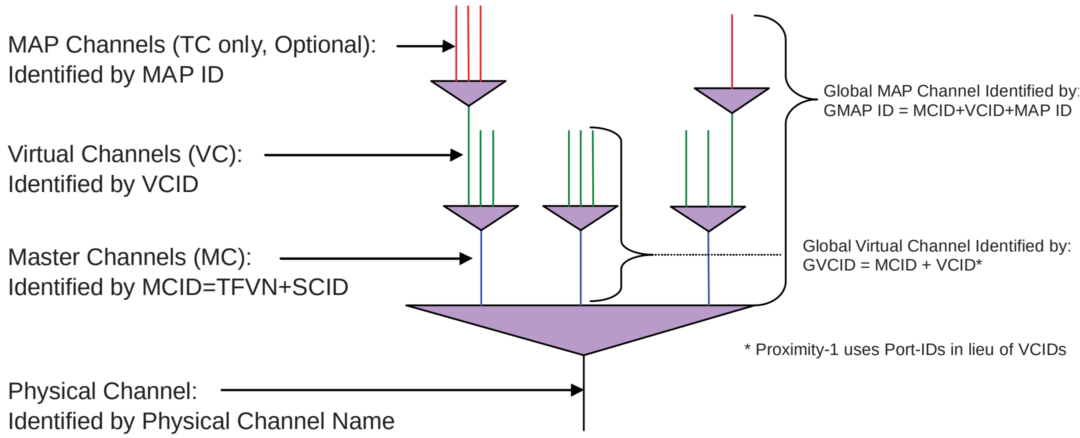


Figure 2-3: Hierarchy of the Identifiers and Channels Used by the CCSDS Space Data Link Protocols

2.2.2 RECOMMENDED CCSDS IP TRANSFER SERVICES

2.2.2.1 Recommended CCSDS IPv4 Transfer Services

Table 2-1 lists the CCSDS recommended IPv4 transfer services over AOS, TM, TC, and Proximity-1 Space Data Link Protocols.

Table 2-1: Recommended CCSDS IPv4 Transfer Services

CCSDS IPv4 Transfer Service	Applicable Space Data Link	Service Access Point (SAP) Address	Service Data Unit
Virtual Channel Packet (VCP)	AOS, TM, TC, Proximity-1	GVCID + PVN	Packet
MAP Packet (MAPP)	TC	GVCID + PVN + MAP ID	Packet
Virtual Channel Access (VCA)	AOS, TM, TC, Proximity-1	GVCID	VCA_SDU (octet-aligned stream)
MAP Access (MAPA)	TC	GVCID + MAP ID	MAP_SDU (octet-aligned stream)
Encapsulation Service (ENCAP)	AOS, TM, TC, Proximity-1	GVCID	Packet

An executive summary of each of these services is provided in table 2-2, below. For a complete description of each service supporting the underlying CCSDS link layer protocol, see the detailed definition of these services in section 4. For guidance in choosing a specific CCSDS IP transfer service, see table 2-3, below.

Table 2-2: Executive Summary of CCSDS IPv4 Transfer Services

CCSDS Service	**Executive Summary**
MAPP	MAP packet service transfers a sequence of variable length, delimited, octet-aligned packets across a space link on a specified Multiplexer Access Point (MAP) channel.† Service is unidirectional and asynchronous.
VCP	Virtual Channel Packet service transfers a sequence of variable length, delimited, octet-aligned packets across a space link. The service is unidirectional and asynchronous. Completeness is not guaranteed, nor are gaps signaled to the receiver.
VCA	Virtual Channel Access service transfers a sequence of privately defined octet-aligned service data units across a space link. The service is unidirectional, either asynchronous or periodic. Completeness is not guaranteed, nor are gaps signaled to the receiver.
MAPA	MAP Access service transfers a sequence of privately defined octet-aligned service data units of variable length across a space link on a specified MAP channel.† Completeness is not guaranteed, nor are gaps signaled to the receiver.
ENCAP	Encapsulation Service transfers protocol data units of authorized protocols (see table 2-4) to a protocol handler over a space link. The service user can input either a) an IP datagram and its associated link layer address to the packet SAP (using protocol ID ‘100’ from table 2-4) or b) an octet-aligned stream (using protocol ID ‘111’ from table 2-4) containing IP datagrams to the octet stream SAP along with its associated link layer address.
† On one MAP Channel, the MAP Access Service shall not exist simultaneously with the MAP Packet Service.	

Table 2-3: Key Characteristics of the CCSDS IPv4 Transfer Services

CCSDS IP Link Layer Transfer Service	Link Layer Protocol	Stream Type	Multiplexing Features	Packet Types Transferred
VCP	AOS, TM, TC, Prox-1	Used to transfer a packet	Contents of frame routed based upon up to 64 VCIDs	IPv4, SCPS-NP, CCSDS Space Packet, Encapsulation Packet
MAPP	TC only	Used to transfer a packet	Provides multiplexing beyond VCs, up to an additional 64 MAP IDs	IPv4, SCPS-NP, CCSDS Space Packet, Encapsulation Packet
VCA	AOS, TM, TC, Prox-1	Used to transfer an octet-aligned stream	Contents of frame routed based upon up to 64 VCIDs	IPv4, SCPS-NP, CCSDS Space Packet, Encapsulation Packet
MAPA	TC only	Used to transfer an octet-aligned stream	Provides multiplexing beyond VCs, up to an additional 64 MAP IDs	IPv4, SCPS-NP, CCSDS Space Packet, Encapsulation Packet
ENCAP	AOS, TM, TC, Prox-1	Used to transfer protocol data units e.g., packets or an octet-aligned stream	One protocol data unit per Encapsulation packet	Fill packet, IP Datagrams, Octet stream, CFDP PDUs

2.2.2.2 Recommended CCSDS IPv6 Transfer Service

An IPv6 datagram can be transferred over a CCSDS space link only through use of the CCSDS Encapsulation Service. The CCSDS Encapsulation Service provides a mechanism for transferring protocol data units of authorized protocols (see table 2-4) to a protocol handler over a space link.

The service user can input either a) an IPv6 datagram and its associated link layer address to the packet SAP (using protocol ID ‘100’ from table 2-4) or b) an octet-aligned stream (using protocol ID ‘111’ from table 2-4) containing IPv6 datagrams to the octet stream SAP along with its associated link layer address. Note that the octet stream is segmented upon input to the SAP into individual ENCAP_SDUs. (See figure 2-2.) Note that the Encapsulation Packet may be split across several CCSDS transfer frames, depending upon the size of the encapsulated IPv6 datagram, and the CCSDS link layer protocol used.

Table 2-4: CCSDS Authorized Protocol Identifiers

Protocol Identifier (binary)	Protocol	Reference
000	Fill (no encapsulation data)	N/A
100	IP	[F8]
011	CFDP	[6]
111	Arbitrary Aggregations of Octets	N/A

The Encapsulation Packet is only used to encapsulate data units that do not contain an authorized CCSDS packet version number. (See table 2-5, below.)

Table 2-5 : CCSDS Authorized Packet Version Numbers

Version Number	Binary Encoded Version Number	Packet	Reference
1	000	CCSDS Space Packet	[F10]
2	001	SCPS-NP	[F11]
3	010 (See NOTE 2 below)	IP Version 4 Datagram	[F7]
8	111	CCSDS Encapsulation Packet	[7]

NOTES

1 In the field of Packet Version Number in the Packets, the Binary Encoded Version Number listed above must be used.

2 The version number field of the IP version 4 Packet has four bits and contains the binary values of ‘0100’. However, the CCSDS Space Data Link Protocols recognize only the first three bits of this field as the Packet Version Number. See annex E for for the interpretation of this field within CCSDS links.

2.2.3 MULTIPLEXING SERVICE DATA UNITS OVER CCSDS LINKS

2.2.3.1 General

This subsection provides a tutorial on how service data units, i.e., CCSDS Space Packets, SCPS-NP datagrams, and IPv4 and IPv6 datagrams are encapsulated and multiplexed at the sending end and demultiplexed, extracted, and routed at the receiving end for each CCSDS Space Data Link Protocol. An executive summary of the key characteristics for each CCSDS link layer protocol is provided below in table 2-6.

Table 2-6: Key Characteristics of CCSDS Link Layer Protocols

CCSDS Link Layer Protocol	Transmission Features	Reception Features	Multiplexing Features	Packet Types Transferred
AOS	1. Fixed Length frame (1115 octet maximum) 2. Used for High Rate uplink or downlink 3. Isochronous Data 4. No frame ARQ	First Header pointer provides for packet resynchronization within the frame stream	Frame Routing based upon 64 VCIDs	IPv4, SCPS-NP, CCSDS Space Packet, Encapsulation Packet
TM	1. Fixed Length frame (1115 octet maximum) 2. Used for Low Rate Downlink 3. No Isochronous Data 4. No frame ARQ	First Header pointer provides for packet resynchronization within the frame stream	Frame Routing based upon 8 VCIDs	IPv4, SCPS-NP, CCSDS Space Packet, Encapsulation Packet
TC	1. Variable Length frame (1024 octet maximum) 2. Used for Low Rate Uplink 3. No Isochronous data 4. COP-1 go-back-N protocol provides frame ARQ	Frame length in transfer frame header delimits frame contents	1. Frame Routing based upon 64 VCIDs 2. Routing at Segmentation Layer up to 64 MAP IDs	IPv4, SCPS-NP, CCSDS Space Packet, Encapsulation Packet
Proximity-1	1. Variable Length frame (2048 octet maximum) 2. Used for Moderate Rate uplink/downlink 3. No Isochronous data 4. COP-P go-back-N protocol provides frame ARQ	Frame length in transfer frame header delimits frame contents	Contents of frame routed to either 8 physical or logical entities via Port IDs per Physical Channel	IPv4, SCPS-NP, CCSDS Space Packet, Encapsulation Packet

NOTE – Low Rate Downlink is defined here to mean <= 100 Kbps; Efficient Low Rate Uplink is bounded by 1 Mbps.

2.2.3.2 AOS Space Data Link

Figure 2-4 provides a tutorial on how SDUs are input into AOS frames, how SDUs are extracted upon output, and how multiple types of service data units can be multiplexed over the AOS frame. The AOS frame is used to transfer relatively high rate telemetry (multiple Mb/sec) directly to Earth without ARQ.

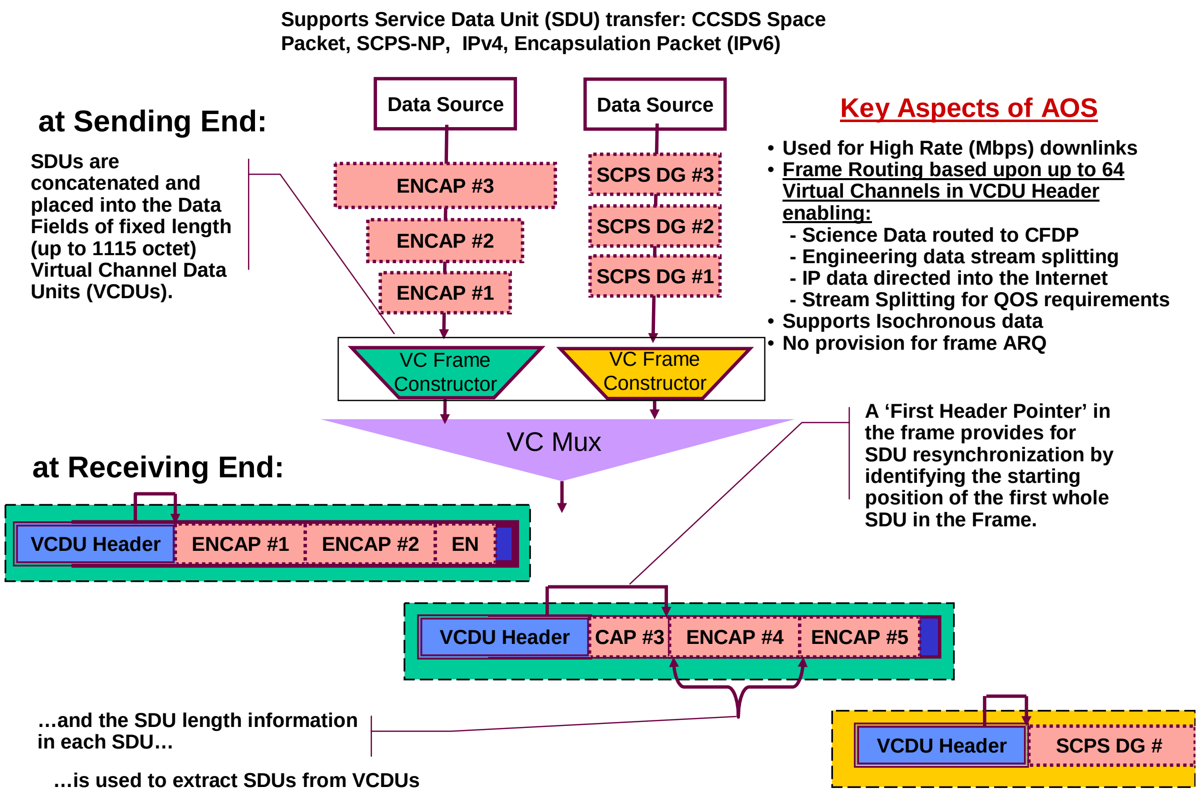


Figure 2-4: Multiplexing SDUs over AOS Frames

In this example, a data source is producing IPv6 datagrams contained one for one within CCSDS Encapsulation Packets while concurrently a second data source is producing CCSDS Space Packets. CCSDS provides the capability of multiplexing both of these SDUs onto the same master channel in two separate ways. Option 1, as shown above, assigns a unique VCID to each SDU type (i.e., CCSDS Space Packets, Encapsulation Packets). Assigning separate VCIDs may be done in order to split out and route these data directly at the ground receiving station. A second option, not shown above, but equally viable, would be to assign a single VCID for both types and multiplex both Encapsulation Packets and CCSDS Space Packets onto it. The receiving system can extract the SDUs from the frame, since each SDU has a defined length field based upon its Packet Version Number (PVN) in the packet header. See annex C for the interpretation of the PVN field for identification of IPv4 datagrams. See table 2-5 for the authorized CCSDS PVNs. For the set of requirements associated with transferring data units over the AOS Space Data link, see reference [3].

2.2.3.3 TM Space Data Link

Figure 2-5 provides a tutorial on how SDUs are input into TM frames, how SDUs are extracted upon output, and how multiple types of service data units can be multiplexed over the TM frame. The TM frame is used to transfer relatively low rate telemetry (multiple Kb/sec) directly to Earth without ARQ.

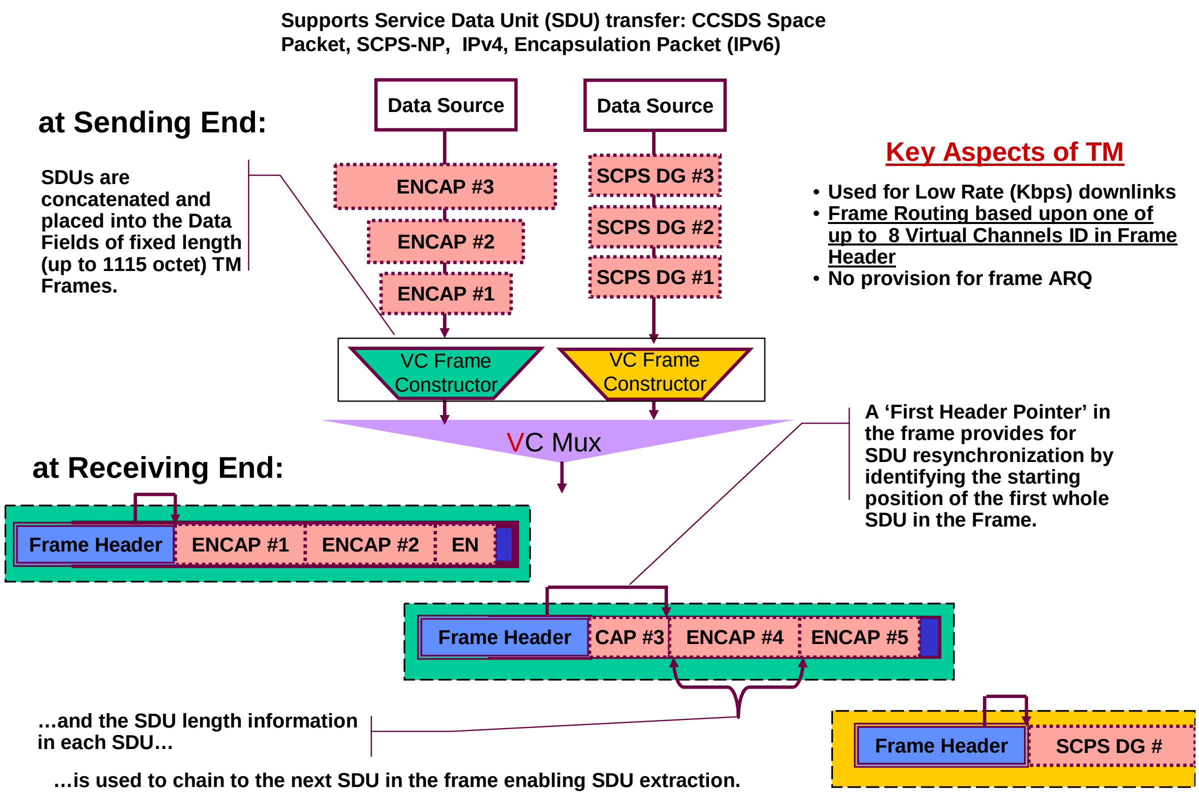


Figure 2-5: Multiplexing SDUs over TM Frames

In this example, a data source is producing IPv6 datagrams contained one for one within CCSDS Encapsulation Packets while concurrently a second data source is producing SCPS datagrams. CCSDS provides the capability of multiplexing both of these SDUs onto the same master channel in two separate ways. Option 1, as shown above, assigns a unique VCID to each SDU type (i.e., SCPS datagrams, Encapsulation Packets). Assigning separate VCIDs maybe done in order to split out and route these data directly at the ground receiving station. A second option, not shown above, but equally viable, would be to assign a single VCID for both types and multiplex both Encapsulation Packets and SCPS datagrams onto the master channel. The receiving system can extract the SDUs from the frame, since each SDU has a defined length field based upon its PVN in the packet header. See annex C for the interpretation of the PVN field for the identification of IPv4 datagrams. See table 2-5 for the authorized CCSDS PVNs. For the overall set of requirements associated with transferring data units over the TM Space Data link, see reference [4].

2.2.3.4 TC Space Data Link

Figure 2-6 provides a tutorial on how SDUs are input into TC frames, how SDUs can be segmented, how both packets and segments are extracted upon output, and how multiple types of service data units can be multiplexed over the TC frame. The TC frame is used to transfer relatively low rate telecommand (multiple Kb/sec) directly from Earth with optional frame ARQ, using the COP-1 protocol (reference [9]).

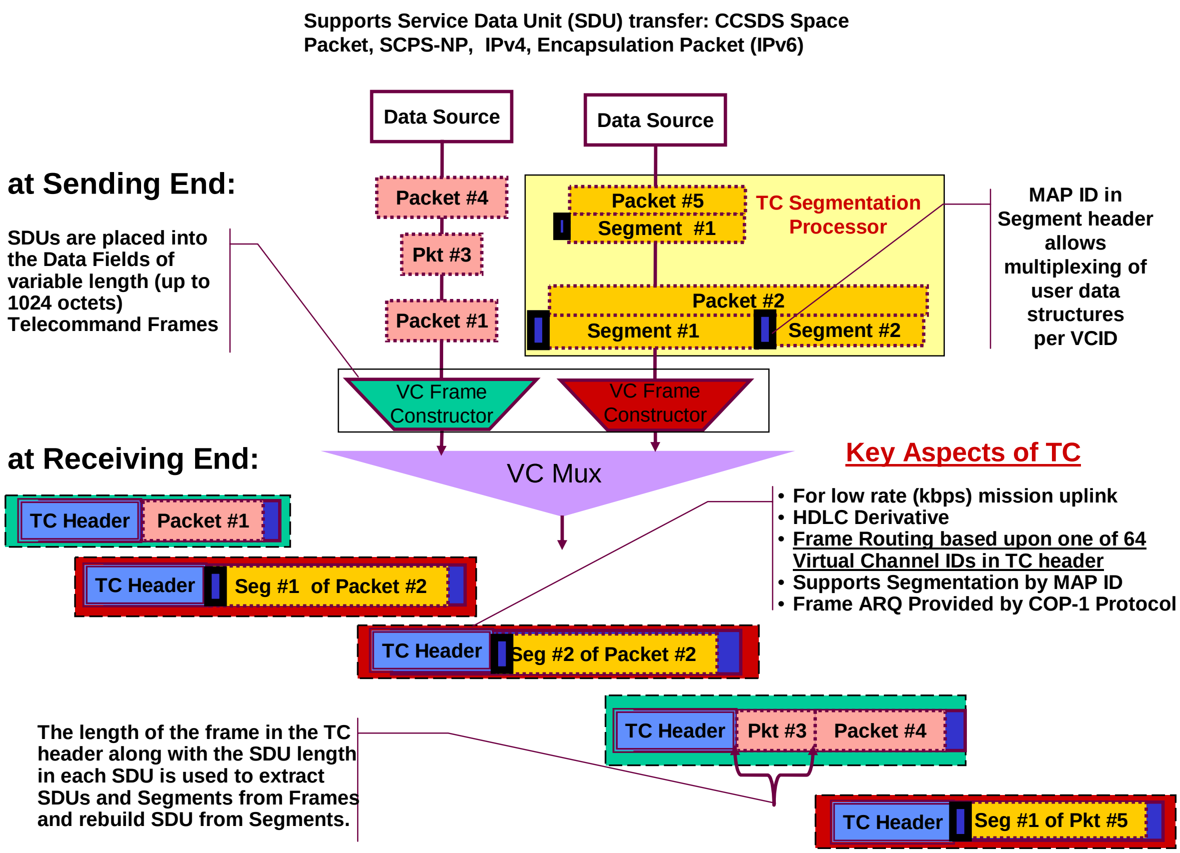


Figure 2-6: Multiplexing SDUs over TC Frames

In this example, a data source is producing packets smaller than the maximum TC frame size (i.e., link layer MTU) over one VC while a second data source is concurrently producing packets mostly larger than the MTU over a second independent VC. TC provides the capability of both aggregating and subdividing SDUs into segments by assigning a MAP ID to each segment. CCSDS requires that once segmentation occurs on a VC, every TC frame assigned to that VC shall contain a segment. Therefore, as figure 2-6 shows, even packets smaller than the MTU are encapsulated into a segment for transmission over that VC. For the set of requirements associated with transferring data units over the TC Space Data link see reference [5].

A MAP is a mechanism provided within the TC Segmentation layer to allow different user data structures to be multiplexed for transmission over one VC provided by the frame layer. Multiplexing at the segment layer allows user data structures with different delivery priorities to share the same VC and thus provides flow control. The SDU arriving at the sending end can optionally be allocated to a MAP and transferred to the corresponding MAP at the receiving end of the segment layer. Similar to AOS and TM, TC also provides the independent capability of multiplexing SDUs at the link layer using VCIDs.

The receiving system can extract the SDUs from the frame, since each SDU has a defined length field based upon its PVN in the packet header. See annex C for the interpretation of the PVN field for the identification of IPv4 datagrams. See table 2-5 for the authorized CCSDS PVNs. For the overall set of requirements associated with transferring data units over the TC Space Data link, see reference [5].

2.2.3.5 Proximity-1 Data Link

Figure 2-7 provides a tutorial on how SDUs are input into Prox-1 frames, how SDUs can be segmented, how both packets and segments are extracted upon output, and how multiple types of service data units can be multiplexed over the Prox-1 frame. The Prox-1 frame is used to transfer moderate rate telecommand and telemetry (up to 2 Mb/sec) in proximate environments with optional frame ARQ, using the COP-P protocol (reference [6]).

In this example, a data source is producing packets smaller than the maximum Prox-1 frame size (i.e., link layer MTU) over one Port ID, while a second data source is concurrently producing packets mostly larger than the MTU over a second independent Port. Prox-1 provides the capability of both aggregating and subdividing SDUs into segments by assigning a ‘pseudo packet ID’ to each segment. Unlike the multiplexer functionality of the TC MAP ID, the pseudo packet ID is a temporary packet ID assigned to enable the protocol to account for the segments of multiple SDUs during transmission. To this end, Prox-1 requires that segments of the same SDU be sent in frames containing the same physical channel ID or Port ID. However, segments from another packet may be interspersed but only in frames containing a different physical channel ID or Port ID.

The receiving system can extract the SDUs from the frame, since each SDU has a defined length field based upon its PVN in the packet header. See annex C for the interpretation of the PVN field for the identification of IPv4 datagrams. See table 2-5 for the authorized CCSDS PVNs. For the overall set of requirements associated with transferring data units over the Prox-1 Space Data link, see reference [6].

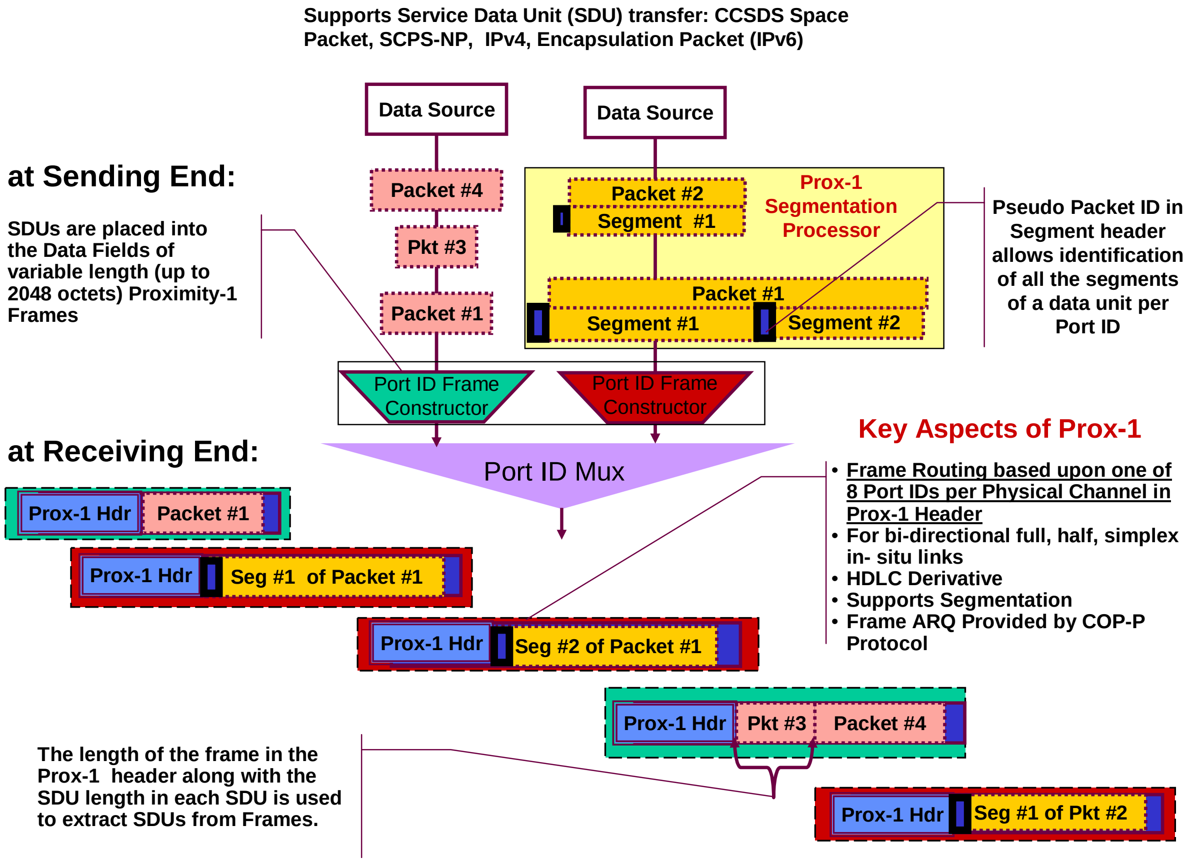


Figure 2-7: Multiplexing SDUs over Proximity-1 Frames

2.2.4 CCSDS IP TRANSFER SERVICE (CCSDS ENCAPSULATION SERVICE)

2.2.4.1 Concept of Encapsulation Service

The Encapsulation Service provides a mechanism for transferring protocol data units of authorized protocols (see table 2-4) to a protocol handler over a space link. It is mandatory to use this service to transfer IPV6 datagrams across CCSDS space links, because IPv6 datagrams do not have a PVN recognized by CCSDS. In the case of IPv4 datagrams, this service is optional and provides a possible migration path for future use of IPv6.

The Encapsulation Service is a service provided by the Data Link Layer of the OSI Basic Reference Model (reference [F9]). (See figure 2-8). It is an extra service of the Space Data Link Protocols defined in references [3]-[6] and therefore shall be used together with one of these references.

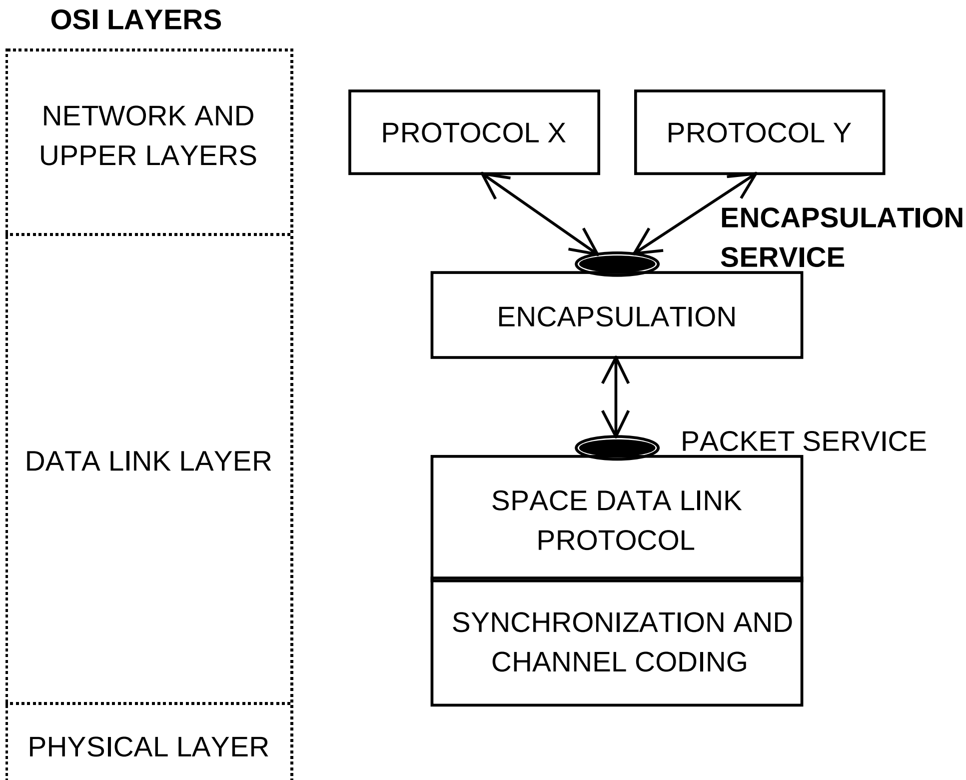


Figure 2-8: Concept of Encapsulation Service

Figure 2-8 illustrates the concept of the Encapsulation Service. Protocol data units of Protocols X and Y, which do not have an authorized PVN, are transferred with the Encapsulation Service within the Data Link Layer. Protocol data units of Protocols X and Y are encapsulated in Encapsulation Packets, defined in reference [7], and are transferred using the Virtual Packet Service of a Space Data Link Protocol. Management shall establish which Space Data Link Protocol is to be used to transfer encapsulated data units.

2.2.4.2 Features of the Encapsulation Service

The Encapsulation Service transfers a sequence of variable-length, delimited, octet-aligned data units with a Space Data Link Protocol over a space link. The format and content of data units transferred with this service are unknown to the service provider.

A data unit supplied by the service user is encapsulated unchanged into an Encapsulation Packet, and no more than one data unit is encapsulated into a single packet. That is, segmenting or blocking of data units is not performed by the service provider.

The service permits a data unit to be of any length which is an integral number of octets, and which is subject to the maximum and minimum sizes established by the project organization. Although the maximum length of a data unit that can be accommodated by an encapsulating packet is 4,294,967,291 octets if the Encapsulation Packet is used, individual project organizations may establish the maximum and minimum sizes for the encapsulated data unit.

The point at which an instance of this service is provided to a user is called a Service Access Point (SAP) (see reference [F9]). Data units submitted to a SAP are processed in the order of submission. No processing order is maintained for data units submitted to different SAPs.

NOTE – Implementations may be required to perform flow control at a SAP between the service user and the service provider. However, CCSDS does not recommend a scheme for flow control between the user and the provider.

Features of the Encapsulation Service are as follows:

a) Unidirectional (one way) service: One end of a connection can send, but not receive, data through the space link, while the other end can receive, but not send, data through the space link.

b) Asynchronous service: There are no timing relationships between the transfer of data units supplied by the user and any data transmission mechanism within the Data Link Layer. The user may request data transfer at any time, but there may be restrictions imposed by the service provider on the data generation rate.

c) Unconfirmed service: The sending user does not receive confirmation from the receiving end indicating that data has been received.

d) Incomplete service: The service does not guarantee completeness, but the service provider may signal gaps in the sequence of data units delivered to the receiving user.

e) Sequence preserving service: The sequence of data units supplied by the sending user is preserved through the transfer over the space link, although there may be gaps in the sequence of data units delivered to the receiving user.

2.2.4.3 ADDRESSING

A user of the Encapsulation Service is identified by the combination of the following:

a) a PVN that indicates that Encapsulation Packets are used for encapsulation; and

b) an Encapsulated Protocol Identifier (EPI).

NOTE – Both the PVN and the EPI are defined in reference [8] and are provided in table A-3, Managed Parameters for Encapsulation Service.

2.2.4.4 SERVICE Description

The Encapsulation Service is described in terms of:

a) the service primitives provided to the users of this service;

b) the protocol data units employed by the service provider for encapsulation; and

c) the procedures performed by the service provider.

The service primitives present an abstract model of the logical exchange of data and control information between the service provider and the service user. The definitions of primitives are independent of specific implementation approaches.

The protocol data units (i.e., the Encapsulation Packet) define the data structure in which data units supplied by the service user are encapsulated.

The procedure specifications define the procedures performed by the service provider for the transfer of data units. The definitions of procedures are independent of specific implementation methods or technologies.

2.3 ROADMAP FOR SELECTING A CCSDS IP TRANSFER SERVICE

Figure 2-1 above provides conceptual guidance in selecting the appropriate CCSDS IP transfer service.

a) Once the user has decided in step 1 on what version of IP to transfer, step 2 involves making the decision of how to delimit the IP datagrams within the data link layer. This recommendation provides three alternative methods of delimiting: CCSDS direct encapsulation into the transfer frame i.e., path 1; CCSDS Encapsulation Service i.e., paths 3 or 4; user-defined encapsulation i.e., paths 2 or 5. The advantage of using the CCSDS methods are that both the AOS and TM CCSDS data link protocol provide a packet resynchronization mechanism, i.e., the first header pointer in each transfer frame header points to the start of the next packet header within the stream of frames. If IP datagrams are transferred as a user defined bit stream, then some form of synchronization must be provided in the stream itself in order for the IP datagrams to be reconstructed, in the event data is missed or arrives in error.

b) Independent of Steps 1 and 2, Step 3 conceptually involves choosing the CCSDS Data Link Layer protocol based upon the constrains the user faces on the data link. See table 2-6 and subsection 2.2.3, Multiplexing Service Data Units over CCSDS Links, which provides a tutorial about each CCSDS data link protocol including the discriminating factors for their use over the space link.

c) Finally in step 4, having chosen a CCSDS link layer protocol and a delimiting method, determines which CCSDS IP transfer service to use. See table 2-6 for the rationale for choosing a CCSDS IP transfer service. Essentially, for IPv4 datagrams, MAP services (i.e., MAPP or MAPA) are used if multiplexing at the segmentation layer using MAP IDs is required. If only multiplexing at the VC is required, then the VC services (VCP or VCA) are used.

d) For IPv6 datagrams, the Encapsulation Service is used, since IPv6 does not contain a PVN authorized by CCSDS. It is recommended that IPv6 datagrams be contained one for one within a CCSDS Encapsulation Packet. The Encapsulation Service allows the data to be transferred either as an octet-aligned stream or as a packet, based upon the protocol ID within the Encapsulation Packet header.

3 PDU FORMATS

3.1 OVERVIEW

This section provides a tutorial of the Protocol Data Units (PDUs) used in the transfer of IP datagrams over CCSDS space data link protocols. For each link layer protocol, the key fields used to address the link layer are indicated and described. In addition, the Encapsulation Service PDU, i.e., Encapsulation Packet, is described.

3.2 AOS TRANSFER FRAME

Figures 3-1 and 3-2 show the components of the AOS transfer frame, i.e., the CCSDS Version 2 frame, having a TFVN of ‘01’ binary.

AOS TRANSFER FRAME				
TRANSFER FRAME PRIMARY HEADER	TRANSFER FRAME INSERT ZONE (Optional)	TRANSFER FRAME DATA FIELD	TRANSFER FRAME TRAILER (Optional)	
			OPERA-TIONAL CONTROL FIELD (Optional)	FRAME ERROR CONTROL FIELD (Optional)
6 or 8 octets	Varies	Varies	4 octets	2 octets

Figure 3-1: AOS Transfer Frame

TRANSFER FRAME PRIMARY HEADER								
MASTER CHANNEL ID		VIRTUAL CHANNEL ID	VIRTUAL CHANNEL FRAME COUNT	SIGNALING FIELD				FRAME HEADER ERROR CONTROL (Optional)
TRANSFER FRAME VERSION NUMBER	SPACECRAFT ID			REPLAY FLAG	VC FRAME COUNT USAGE FLAG	RSVD. SPARE	VC FRAME COUNT CYCLE	
2 bits	8 bits	6 bits		1 bit	1 bit	2 bits	4 bits	
2 octets			3 octets	1 octet				2 octets

NOTE – For any given AOS link this field is fixed per mission phase and telemetry mode.

Figure 3-2: AOS Transfer Frame Primary Header

The length of the AOS Transfer Frame Data Field into which the spacecraft application data is placed varies and is a managed parameter. The maximum transfer frame length is dependent upon the coding used and is defined in reference [F12].

The AOS Transfer Frame key fields used by the CCSDS IPv4 transfer services (see section 4) are:

a) Transfer Frame Version Number (TFVN), a two-bit field at the start of the Transfer Frame Header, containing the binary value ‘01’;

b) Spacecraft ID (SCID), an eight-bit field that immediately follows the TFVN field;

c) Virtual Channel ID (VCID), a six-bit field that immediately follows the SCID field.

For a complete description of all of the fields within the AOS frame, see reference [3].

3.3 TM TRANSFER FRAME

Figures 3-3 and 3-4 show the components of the TM transfer frame, i.e., the CCSDS Version 1 frame, having a TFVN of ‘00’ binary.

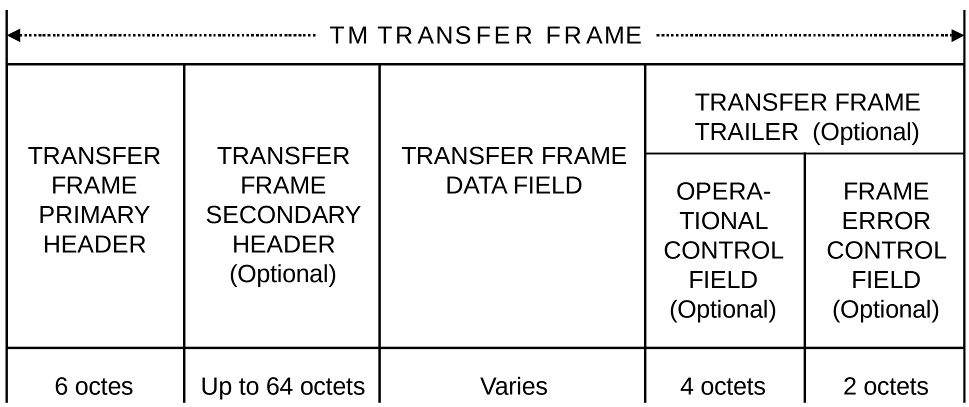


Figure 3-3: TM Transfer Frame

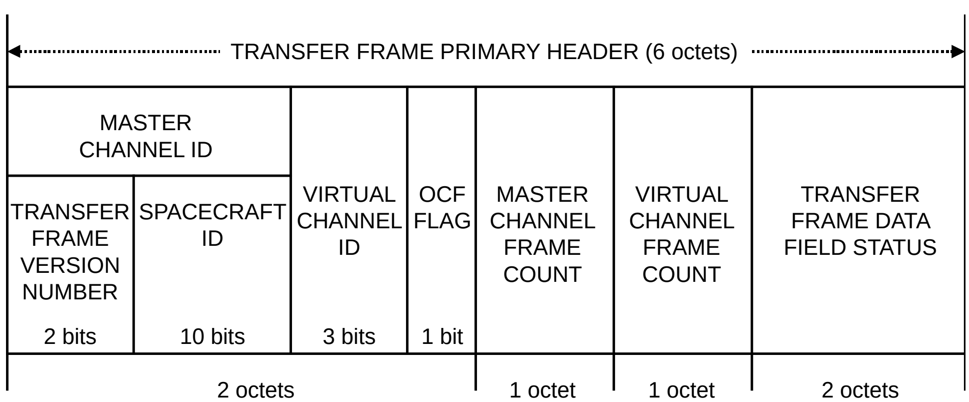


Figure 3-4: TM Transfer Frame Primary Header

The length of the Transfer Frame Data Field into which the spacecraft application data is placed varies and is a managed parameter. The maximum transfer frame length is dependent upon the coding used and is defined in reference [F12].

The TM Transfer Frame key fields used by CCSDS IP transfer services (see section 4) are:

a) Transfer Frame Version Number (TFVN), a two-bit field at the start of the Transfer Frame Header, containing the binary value ‘00’;

b) Spacecraft ID (SCID), a ten-bit field that immediately follows the TFVN field;

c) Virtual Channel ID (VCID), a three-bit field that immediately follows the SCID field.

For a complete description of all of the fields within the TM frame, see reference [4].

3.4 TC TRANSFER FRAME

Figures 3-5 and 3-6 show the components of the TC transfer frame, i.e., the CCSDS Version 0 frame, having a TFVN of ‘00’ binary.

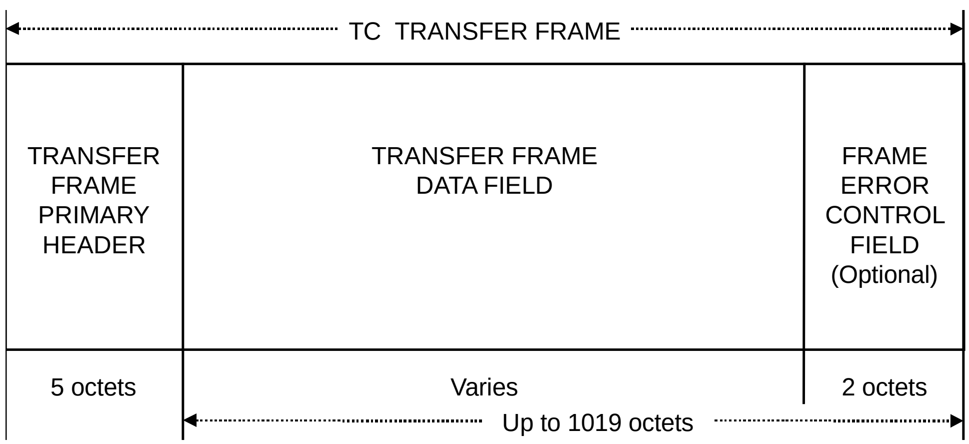


Figure 3-5: TC Frame Structure

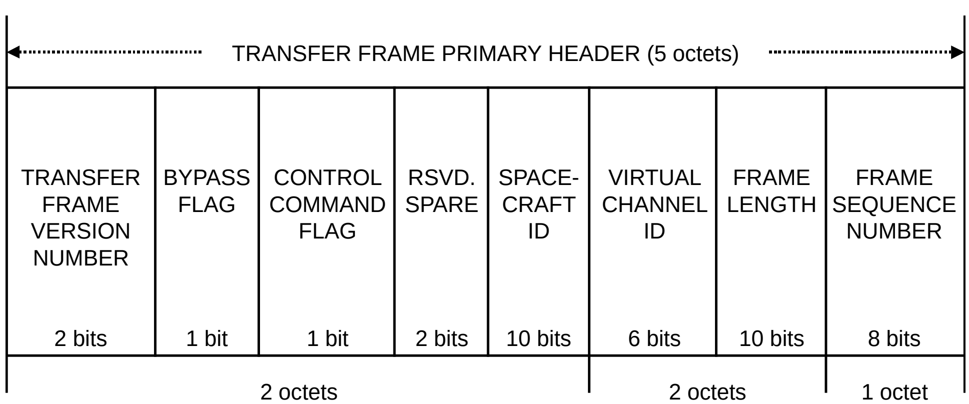


Figure 3-6: TC Frame Primary Header

The length of the Transfer Frame Data Field into which the spacecraft application data is placed varies with the size of the packet or VCA_SDU and is defined by the Frame Length Field. The maximum TC frame length is 1024 octets.

The TC Transfer Frame key fields used by CCSDS IP transfer services (see section 4) are:

a) Transfer Frame Version Number (TFVN), a two-bit field at the start of the Transfer Frame Header, containing the binary value ‘00’;

b) Spacecraft ID (SCID), a ten-bit field within the Transfer Frame Header;

c) Virtual Channel ID (VCID), a six-bit field that immediately follows the SCID field.

For a complete description of all of the fields within the TC frame, see reference [5].

3.5 PROX-1 TRANSFER FRAME

Figures 3-7 and 3-8 show the components of the Prox-1 transfer frame, i.e., the CCSDS Version 3 frame, having a TFVN of ‘10’ binary.

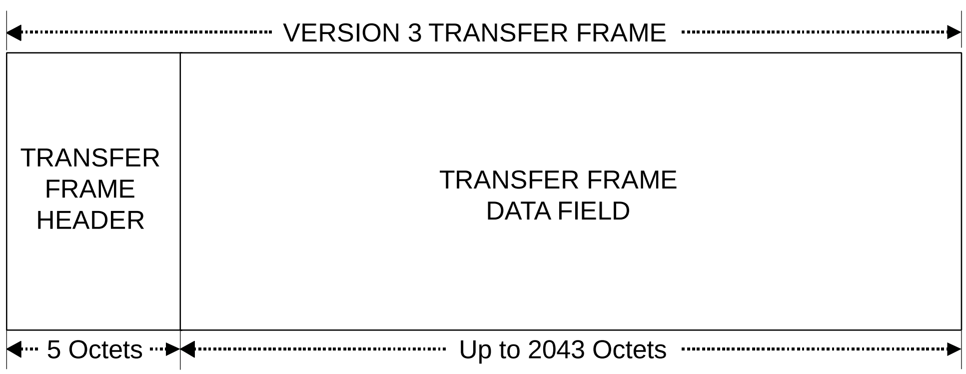


Figure 3-7: Prox-1 Primary Transfer Frame Header

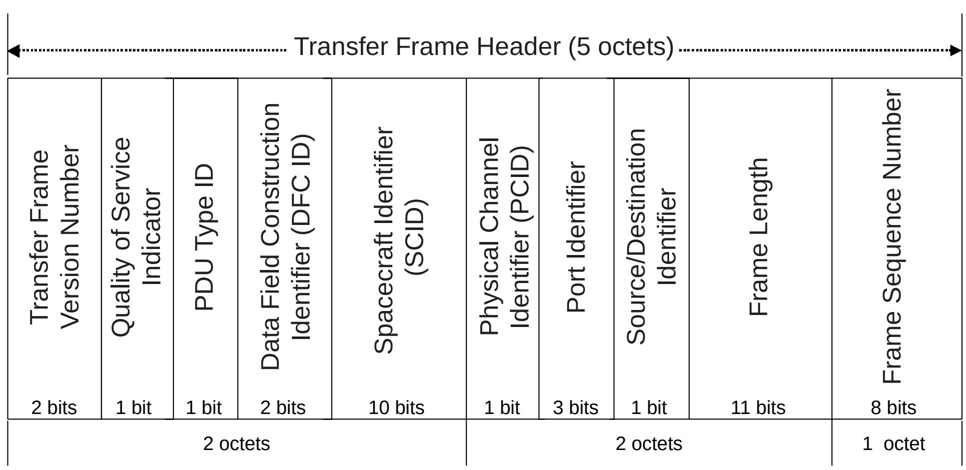


Figure 3-8: Proximity-1 Transfer Frame Header

The length of the Transfer Frame Data Field into which the spacecraft application data is placed varies with the size of the packet or SDU and is defined by the Frame Length Field. The maximum Prox-1 frame size is 2048 octets.

The Prox-1 Transfer Frame key fields used by CCSDS IP transfer services (see section 4) are:

a) Transfer Frame Version Number (TFVN), a two-bit field at the start of the Transfer Frame Header, containing the binary value ‘10’;

b) Spacecraft ID (SCID), a ten-bit field within the Transfer Frame Header;

c) Port Identifier (Port ID), a three-bit field that immediately follows the SCID field.

For a complete description of all of the fields within the Prox-1 frame, see reference [6].

3.6 ENCAPSULATION PACKET STRUCTURE

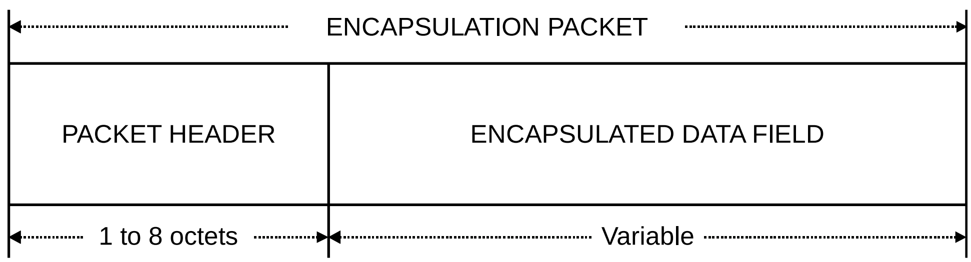


Figure 3-9: Encapsulation Packet Structural Components

3.6.1 ENCAPSULATION PACKET HEADER

3.6.1.1 General

The Packet Header is mandatory and shall consist of three, four, five, or six fields, positioned contiguously, in the following sequence:

a) Packet Version Number (3 bits, mandatory);

b) Protocol ID (3 bits, mandatory);

c) Length of Length (2 bits, mandatory);

d) User Defined Field (4 bits; mandatory in 4- and 8-octet headers; not used in 1- and 2-octet headers—see figure 3-10);

e) Protocol ID Extension Field (4 bits; mandatory in 4- and 8-octet headers; not used in 1- and 2-octet headers—see figure 3-10);

f) CCSDS Defined Field (2 octets; mandatory in 8-octet headers; not used in 1-, 2-, and 4-octet headers—see figure 3-10);

g) Packet Length (0, 1, 2, or 4 octets; mandatory in 2-, 4-, and 8-octet headers; not used in 1-octet headers—see figure 3-10).

The format of the Packet Header is shown in figure 3-10.

ENCAPSULATION PACKET HEADER

PACKET VERSION NUMBER 3 bits	PROTOCOL ID 3 bits	LENGTH OF LENGTH 2 bits	USER DEFINED FIELD 0 or 4 bits	PROTOCOL ID EXTENSION 0 or 4 bits	CCSDS DEFINED FIELD 0 or 2 octets	PACKET LENGTH 0 to 4 octets
‘111’	‘XXX’	‘00’	0 bits	0 bits	0 octets	0 octets
‘111’	‘XXX’	‘01’	0 bits	0 bits	0 octets	1 octet
‘111’	‘XXX’	‘10’	4 bits	4 bits	0 octets	2 octets
‘111’	‘XXX’	‘11’	4 bits	4 bits	2 octets	4 octets

Figure 3-10: Packet Header

3.6.1.2 Packet Version Number

Bits 0-2 of the Packet Header shall contain the (Binary Encoded) Packet Version Number.

This 3-bit field shall identify the data unit as an Encapsulation Packet defined by this subsection; it shall be set to ‘111’.

NOTE – The Version Number is used to reserve the possibility of introducing other packet structures. This subsection defines ‘Encapsulation Packet (Version 8 CCSDS Packet)’ whose Binary Encoded Version Number is ‘111’.

3.6.1.3 Protocol ID

Bits 3-5 of the Packet Header shall contain the Protocol ID.

The Protocol ID shall be used to identify the protocol whose data units are being encapsulated.

The Protocol IDs allowed by CCSDS for the Encapsulation Packet shall be registered in reference [8].

The value ‘110’ in the Protocol ID field shall signal that the 4-bit Protocol ID Extension field is used for protocol identification.

NOTE – The protocol ID ‘111’ is used for sending mission-specific, privately defined data (i.e., not data units of a protocol to which a Protocol ID is assigned in reference [8]) with the Encapsulation Packet).

3.6.1.4 Length of Length

Bits 6-7 of the Packet Header shall contain the Length of Length.

The Length of Length shall be used to specify the length of the Packet Length field.

The values of this field shall be interpreted as shown in table 3-1.

Table 3-1: Interpretation of Length of Length field

Value of 'Length of Length' Field (binary)	Length of 'Packet Length' Field
00	0
01	1 octet
10	2 octets
11	4 octets

The value '00' of the Length of Length field shall only be used for Encapsulation Packets with Protocol ID '000' (i.e., Fill Packets).

NOTE - When the value of the Length of Length field is '00', there is no Packet Length field in the Packet Header, and there is no Encapsulated Data Unit field in the Encapsulated Packet. Therefore the length of the Encapsulated Packet is one octet. *This one-octet Encapsulation Packet can thus also be used as a single, self-identified octet of fill which may be cascaded to provide any number of octets to fill a fixed-length Transfer Frame used in references [4] and [5]*.

3.6.1.5 User Defined Field

If present, the User Defined field shall be four bits in length and shall follow, without gap, the Length of Length field.

The User Defined field shall be used for sending mission-specific, privately defined header data.

3.6.1.6 Protocol ID Extension

If present, the Protocol ID Extension field shall be four bits in length and shall follow, without gap, the User Defined Field.

The Protocol ID Extension field shall be used to identify the protocol whose data units are being encapsulated.

The extended protocol IDs allowed by CCSDS for the Encapsulation Packet shall be registered in reference [8].

3.6.1.7 CCSDS Defined Field

If present, the CCSDS Defined field shall be two octets in length and shall follow, without gap, User Defined field.

CCSDS Defined field is reserved for future use by CCSDS and is by convention set to ‘all zeros’.

3.6.1.8 Packet Length

If present, the Packet Length field shall follow, without gap, the Length of Length field be the final field in the Encapsulation Packet header (see figure 3-10).

If the value of the Length of Length field is ‘00’, the Packet Length field shall be absent. Otherwise, the Packet Length field shall contain a binary number corresponding to the total length of the Encapsulation Packet (in octets), including the Packet Header.

NOTES

1 Although unlikely to be used in space, a 4-octet Packet Length field permits accommodating IPv6 (reference [F8]) ‘Jumbograms’ up to 4,294,967,291 (=2^{32}-5) octets in length.

2 If the Packet Length field is absent (i.e., the value of the Length of Length field is ‘00’), then the length of the Encapsulation Packet is one octet.

3.6.2 ENCAPSULATED DATA FIELD

If present, the Encapsulated Data Field shall follow, without gap, the Packet Length field.

If the value of the Length of Length field is ‘00’, the Encapsulated Data Field shall be absent. Otherwise, it shall contain a data unit supplied by the service user, which consists of an integral number of octets.

4 SERVICE PRIMITIVES

4.1 BASIC MODEL

Each of the CCSDS transfer services utilizes primitives for transferring its associated data unit. Figure 4-1 shows the basic model used by all of the CCSDS data transfer service primitives defined in this document. The service user requests the transfer of a data unit, i.e., a packet, VCA_SDU, MAP_SDU, or ENCAP SDU by submitting the appropriate *.request* primitive to the service provider. Once the .request is successfully received, the service provider sends back an optional acknowledgement in the form of an *.indication* primitive to the service user.

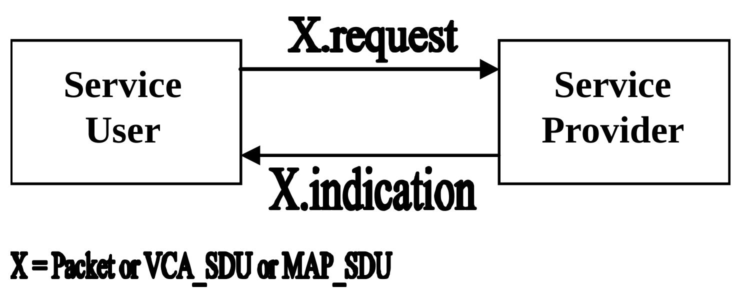


Figure 4-1: CCSDS Generic Data Unit Transfer Primitives

4.2 SELECTION OF CCSDS IPV4 PACKET SERVICES

The two packet services supported by CCSDS to transfer IPv4 datagrams across the space link are: 1) Virtual Channel Packet (VCP) Service and 2) MAP Packet (MAPP) Service.

It is recommended to use the MAPP service supported exclusively by the TC Space Data Link Protocol, if multiplexing of telecommand data units is required at the segmentation layer utilizing MAP IDs. (See reference [F2].) Otherwise, utilize the VCP service of the AOS, TM, TC, and Prox-1 links.

4.3 PROTOCOL PROCEDURES AT THE SENDING END

This subsection describes how the service user supplies IPv4 datagrams and the user's SAP address to the service provider, who carries out the transfer of these datagrams by directly placing them into the Transfer Frame Data Field of the applicable CCSDS transfer frame. In order to have an IPv4 datagram transferred over a CCSDS space data link, the service user provides a *.request primitive* to the service provider. The service user identifies himself to the service provider by specifying its SAP address based upon the service requested. The GVCID is the Global VCID field and the PVN is the Packet Version Number of the packet being transferred.

For VCP service, the SAP address, i.e., the GVCID, decomposes into the following subfields as follows: GVCID = TFVN + SCID + VCID.

Essentially the GVCID tells the service provider over what CCSDS link layer protocol (TFVN) and VC (VCID) to send the authorized (PVN) packet to/from the addressed (SCID) spacecraft. Upon receipt of the PACKET.request primitive, the service provider sends back a PACKET.indication primitive to the service user.

For MAPP service, the SAP address, i.e., GMAP ID, includes the MAP ID of the channel:

GMAP ID = TFVN + SCID + VCID + MAP ID.

4.4 VCP SERVICE SUPPORTED BY AOS AND TM

Both the AOS and TM Space Data Link Protocols support the transfer of packets across the space link using the following service primitives:

Table 4-1: VCP Primitives Supported by AOS or TM

Data Link	Service Type	Service Primitive	Function	Semantics
AOS or TM	*VCP*	Request	Service user requests packet transfer.	PACKET.request(Packet, GVCID, PVN)
AOS or TM	*VCP*	Indication	Sent to the user when a Packet is ready to be delivered.	PACKET.indication(Packet, GVCID, PVN, Packet Quality Indicator (optional))

4.5 VCP SERVICE SUPPORTED BY TC OR PROX-1

4.5.1 GENERAL

Both the TC and Prox-1 Space Data Link Protocols support the transfer of packets across the space link using the following VCP service primitives:

Table 4-2: VCP Primitives Supported by TC or Prox-1

Data Link	Service Type	Service Primitive	Function	Semantics
TC or Prox-1	*VCP*	Request	Service user requests packet transfer.	VCP.request(Packet, GVCID, PVN, SDU ID, Service Type)
TC or Prox-1	*VCP*	Indication	Sent to the user when a Packet is ready to be delivered.	VCP.indication(Packet, GVCID, PVN, Service Type, Packet Quality Indicator)
TC or Prox-1	*VCP*	Notify Indication	Sent to notify the user of an event associated with the transfer of a Packet.	VCP_Notify.indication(GVCID, PVN, SDU ID, Service Type, Notification Type)

In addition to the Packet, GVCID, and PVN parameters explained in 4.3 above, both the TC and Prox-1 Space Data Link protocols share the notion of service type. Essentially both protocols support expedited or sequence-controlled data transfer. The service type parameter in table 4-2 allows a user to specify the data delivery quality of service (sequence-controlled vs. expedited) for the underlying CCSDS link layer protocol supporting the packet transfer.

For TC, the additional VCP service parameters are discussed in 4.5.2- 4.5.5 below.

4.5.2 SDU ID

The SDU ID parameter shall contain a user-supplied sequence number to be used to identify the associated Packet in subsequent VCP_Notify.indication primitives.

4.5.3 SERVICE TYPE

The Service Type parameter shall indicate whether the Packet should be transferred with the Sequence-Controlled Service or the Expedited Service.

When separate ports are provided for Sequence-Controlled and Expedited Services, the Service Type parameter is not used.

At the receiving end, the Service Type parameter is not used.

4.5.4 NOTIFICATION TYPE

In notifications to the user, the Notification Type parameter shall contain information about an event associated with the transfer of a Packet. The values taken by this parameter are defined in COP-1.

4.5.5 PACKET QUALITY INDICATOR (OPTIONAL)

The Packet Quality Indicator shall indicate whether the Packet delivered by the service provider to the service user at the receiving end is complete or not.

This parameter shall be used only when the service provider is required to deliver incomplete Packets to the service user at the receiving end.

4.6 MAP PACKET (MAPP) SERVICE SUPPORTED BY TC

The MAP Packet (MAPP) Service transfers a sequence of variable-length, delimited, octet-aligned service data units known as Packets across a space link on a specified MAP Channel. The Packets transferred by this service must be assigned a PVN by CCSDS. For the Packet Version Numbers presently authorized by CCSDS, see table 2-5.

The service is unidirectional and asynchronous. Both Sequence-Controlled (Type-A) and Expedited (Type-B) service types are provided for the MAPP Service. The user requests with a parameter of the service request primitive whether Type-A or Type-B should be applied for each Packet, or uses one port for Type-A Packets and another port for Type-B Packets.

A user of this service is a protocol entity identified with the PVN and a GMAP ID (i.e., a GVCID and a MAP ID) that sends or receives Packets with a single PVN. Different users (i.e., Packets with different versions) can share a single MAP Channel, and if there are multiple users on a MAP Channel, the service provider multiplexes Packets of different versions to form a single stream of Packets to be transferred on that MAP Channel.

Table 4-3: MAPP Service Primitives

Data Link	Service Type	Service Primitive	Function	Semantics
TC	*MAPP*	Request	Service user requests Map packet transfer.	MAPP.request(Packet, GVCID, MAP_ID, PVN, SDU ID, Service Type)
TC	MAPP	Notify indication	Sent to notify the user of an event associated with the transfer of a Packet.	MAPP_Notify_indication(GVCID, MAP_ID, PVN, SDU ID, Service Type, Notification Type)
TC	*MAPP*	Indication	Sent to the user when a Packet is ready to be delivered.	MAPP.indication(Packet, GVCID, PVN, SDU ID, Service Type (optional))

4.7 SELECTION OF OCTET-ALIGNED STREAM SERVICES

4.7.1 GENERAL

The two octet-aligned stream services supported by CCSDS to transfer IPv4 datagrams across the space link are: 1) VCA Service and 2) MAPA Service. It is recommended to use the MAPA service supported exclusively by the TC Space Data Link Protocol, if multiplexing of telecommand data is required at the segmentation layer utilizing MAP IDs. (See reference [F2].) Otherwise, utilize the VCA service of the AOS, TM, TC, and Prox-1 links.

4.7.2 VCA TRANSFER SERVICES SUPPORTED BY AOS OR TM

Table 4-4: VCA Primitives Supported by AOS and TM

Data Link	Service Type	Service Primitive	Function	Semantics
AOS	*VCA*	Request	Service user requests a VCA_SDU transfer.	VCA.request(VCA_SDU, GVCID)
AOS	*VCA*	Indication	Sent to the user when a VCA_SDU is ready to be delivered.	VCA.indication(VCA_SDU, GVCID, VCA_SDU Loss Flag (optional))
TM	*VCA*	Request	Service user requests a VCA_SDU transfer.	VCA.request(VCA_SDU, VCA Status Fields, GVCID)
TM	*VCA*	Indication	Sent to the user when a VCA_SDU is ready to be delivered.	VCA.indication(VCA_SDU, VCA Status Fields, GVCID, VCA_SDU Loss Flag (optional))

4.7.2.1 Overview

This subsection describes how the service user supplies a sequence of octet-aligned, fixed-length privately defined service data units called VCA_SDUs to the service provider, who carries out their transfer over the AOS or TM space link. The service is unidirectional, either asynchronous or periodic, and sequence preserving. The service does not guarantee completeness (depending upon link or higher layer ARQ), but it may signal gaps in the sequence of service data units delivered to the receiving user.

The service user identifies himself to the service provider by means of specifying its SAP address, i.e., the GVCID. Upon input the user must provide the octet-aligned stream, a gated clock, and a serial port number.

Only one user, identified with the GVCID of the VC, can use this service on a VC. Unlike Packet Service, VCA_SDUs from different users are not multiplexed together within one VC.

4.7.2.2 VCA Service Parameters

4.7.2.2.1 General

The parameters used by the VCA Service primitives shall conform to the specifications contained in table 4-4.

4.7.2.2.2 VCA Status Fields (applicable to TM only)

The Packet Order Flag (one bit) and Segment Length ID (two bits) may be used to convey information on the validity, sequence, or other status of the VCA_SDUs. Provision of this field is mandatory; semantics are user-optional.

NOTE – The VCA Status Fields parameter consists of the Transfer Frame First Header Pointer Field and three other bits of the Transfer Frame Status Field: the Packet Order Flag (one bit), and Segment Length ID (two bits). These are undefined by CCSDS when a VC is used to transfer VCA_SDUs.

4.7.2.2.3 GVCID

The GVCID parameter shall contain a GVCID that indicates the VC through which the VCA_SDU is to be transferred.

NOTE – The GVCID parameter is the SAP address of the VCA Service.

4.7.2.2.4 VCA_SDU Loss Flag

The VCA_SDU Loss Flag is an optional parameter that may be used to notify the user at the receiving end of the VCA Service that a sequence discontinuity has been detected and that one or more VCA_SDUs have been lost. If implemented, the flag shall be derived by examining the Virtual Channel Frame Count in the Transfer Frames.

4.7.3 VCA TRANSFER SERVICES SUPPORTED BY TC OR PROX-1

Table 4-5: VCA Primitives Supported by TC or Prox-1 (TBD)

Data Link	Service Type	Service Primitive	Function	Semantics
TC or Prox-1	*VCA*	Request	Service user requests a VCA_SDU transfer.	VCP.request(VCA_SDU, GVCID, SDU ID, Service Type (optional))
TC or Prox-1	*VCA*	Indication	Sent when a VCA_SDU is ready to be delivered to the user.	VCP.indication(VCA_SDU, GVCID, Service Type (optional))
TC or Prox-1	*VCA*	Notify Indication	Sent to notify the user of an event associated with the transfer of a VCA_SDU.	VCA_Notify.indication(GVCID, SDU ID, Service Type, Notification Type)

4.7.3.1 Overview

The VCA Service provides transfer of a sequence of privately formatted service data units of variable length across a space link. The length of the service data units transferred by this service should not exceed the maximum length of the Data Field of the Transfer Frame.

The service is unidirectional and asynchronous. Both Sequence-Controlled (Type-A) and Expedited (Type-B) service types are provided for the VCA Service. The user requests with a parameter of the service request primitive whether Type-A or Type-B should be applied for each service data unit, or uses one port for Type-A service data units and another port for Type-B service data units.

Only one user, identified with the GVCID of the VC, can use this service on a VC. Service data units from different users are not multiplexed together within one VC.

4.7.3.2 VCA Service Parameters

4.7.3.2.1 VCA_SDU

The VCA_SDU parameter shall contain a VCA_SDU to be transferred on the VC identified by the GVCID.

NOTE – The VCA_SDU is the service data unit transferred by the VCA Service.

4.7.3.2.2 GVCID

The GVCID parameter shall contain the GVCID of the VC through which the VCA_SDU is to be transferred. For restrictions on the VCA_SDUs transferred by the VCA Service, see 4.7.3.1.

4.7.3.2.3 SDU ID

The SDU ID parameter shall contain a user-supplied sequence number to be used to identify the associated VCA_SDU in subsequent VCA_Notify.indication primitives.

4.7.3.2.4 Service Type

The Service Type parameter shall be used to indicate whether the VCA_SDU should be transferred with the Sequence-Controlled Service type (Type-A) or the Expedited Service type (Type-B).

When separate ports are provided for Type-A and Type-B Services, the Service Type parameter is not used.

At the receiving end, the Service Type parameter is not used.

4.7.3.2.5 Notification Type

In notifications to the user, the Notification Type parameter shall contain information about an event associated with the transfer of a VCA_SDU. The values taken by this parameter are defined in reference [8].

4.8 MAP ACCESS (MAPA) SERVICE

4.8.1 MAPA SERVICE PRIMITIVES

Table 4-6: MAPA Primitives Supported by TC

Data Link	Service Type	Service Primitive	Function	Semantics
TC	*MAPA*	Request	Service user requests a MAP_SDU transfer.	MAPA.request(MAP_SDU, GVCID, MAP_ID, SDU_ID, Service type)
TC	*MAPA*	Indication	Sent when a MAP_SDU is ready to be delivered to the user.	MAPA.indication(MAP_SDU, GVCID, MAP_ID, Service type (optional))
TC	*MAPA*	Notify.indication	Sent to notify the user of an event associated with the transfer of a MAP_SDU.	MAPA_Notify.indication(GVCID, MAP_ID, SDU_ID, Service type, Notification type)

4.8.1.1 Overview

The MAP Access (MAPA) Service provides transfer of a sequence of privately formatted service data units of variable length across a space link. The length of the service data units transferred by this service is not constrained by the length of the Data Field of the Transfer Frame.

The service is unidirectional and asynchronous. Both Sequence-Controlled (Type-A) and Expedited (Type-B) service types are provided for the MAPA Service. The user requests with a parameter of the service request primitive whether Type-A or Type-B should be applied for each service data unit, or uses one port for Type-A service data units and another port for Type-B service data units.

Only one user, identified with the GMAP ID (i.e., GVCID and MAP ID) of the MAP Channel, can use this service on a MAP Channel. Service data units from different users are not multiplexed together within one MAP Channel.

4.8.1.2 MAPA SERVICE PARAMETERS

4.8.1.2.1 MAP_SDU

The MAP_SDU parameter shall contain a MAP_SDU to be transferred over the MAP channel identified by MAP ID.

NOTE – The MAP_SDU is the service data unit transferred by the MAPA Service. For restrictions on the MAP_SDUs transferred by the MAPA Service, see 4.8.1.1.

4.8.1.2.2 GVCID

The GVCID parameter shall contain the GVCID of the VC through which the MAP_SDU is to be transferred.

NOTE – The GVCID consists of an MCID and a VCID and is part of the SAP address of the MAPA Service.

4.8.1.2.3 MAP ID

The MAP ID parameter shall contain the MAP ID of the MAP Channel (within the VC specified by GVCID) through which the MAP_SDU is to be transferred.

NOTE – The MAP ID is part of the SAP address of the MAPA Service.

4.8.1.2.4 SDU ID

The SDU ID parameter shall contain a user-supplied sequence number to be used to identify the associated MAP_SDU in subsequent MAPA_Notify.indication primitive.

4.8.1.2.5 Service Type

The Service Type parameter shall indicate whether the MAP_SDU should be transferred with the Sequence-Controlled Service type (Type-A) or the Expedited Service type (Type-B).

When separate ports are provided for Type-A and Type-B Services, the Service Type parameter is not used.

At the receiving end, the Service Type parameter is not used.

4.8.1.2.6 Notification Type

In notifications to the user, the Notification Type parameter shall contain information about an event associated with the transfer of a MAP_SDU. The values taken by this parameter are defined in reference [8].

4.9 ENCAPSULATION SERVICE DEFINITION

4.9.1 OVERVIEW

This subsection provides service definition in the form of primitives, which present an abstract model of the logical exchange of data and control information between the service provider and the service user. The definitions of primitives are independent of specific implementation approaches.

The parameters of the primitives are specified in an abstract sense and specify the information to be made available to the user of the primitive. The way in which a specific implementation makes this information available is not constrained by this specification. In addition to the parameters specified in this subsection, an implementation may provide other parameters to the service user (e.g., parameters for controlling the service, monitoring performance, facilitating diagnosis, and so on).

4.9.2 SERVICE PRIMITIVES

4.9.2.1 General

The service primitives associated with the Encapsulation Service are shown in table 4-7.

Table 4-7: Encapsulation Packet Service Primitives

Data Link	Service Type	Service Primitive	Function	Semantics
AOS, TM, TC, Prox-1	*Encapsulation*	Request	Service user requests a data unit be transferred into an Encapsulation Packet over a Space Data Link Layer protocol.	ENCAPSULATION.request(data unit, GVCID, PVN, EPI)
AOS, TM, TC, Prox-1	*Encapsulation*	Indication	Sent when an Encapsulation Packet is ready to be delivered to the user.	ENCAPSULATION.indication(data unit, GVCID, PVN, EPI, Data Unit Loss Flag (optional))

4.9.2.2 Encapsulation Service Parameters

4.9.2.2.1 Data Unit

Data Unit is the service data unit transferred by the Encapsulation Service, and it shall be a delimited, octet-aligned data unit.

Although the maximum length of a data unit that can be accommodated in an encapsulating packet is 4,294,967,291 octets if the Encapsulation Packet is used, individual project organizations may establish the maximum and minimum sizes for the encapsulated data unit.

4.9.2.2.2 GVCID

The GVCID is part of the SAP address of the Encapsulation Service, and it shall indicate the VC of the underlying Space Data Link Protocol through which the Data Unit is to be transferred.

4.9.2.2.3 PVN

The PVN is part of the SAP address of the Encapsulation Service, and it shall indicate whether the Space Packet or the Encapsulation Packet is to be used for encapsulating the Data Unit (see table A-3).

4.9.2.2.4 EPI

The Encapsulated Protocol Identifier (EPI) is part of the SAP address of the Encapsulation Service. See table 2-4 for CCSDS authorized protocol IDs.

4.9.2.2.5 Data Unit Loss Flag

The Data Unit Loss Flag is an optional parameter that may be used to notify the user at the receiving end of the Encapsulation Service that a sequence discontinuity has been detected and that one or more Data Units have been lost.

4.9.3 PROCEDURES AT THE SENDING END

NOTE – This subsection describes procedures for providing the Encapsulation Service at the sending end. (See figure 4-2.) The procedures described here are defined in an abstract sense and are not intended to imply any particular implementation approach of the service.

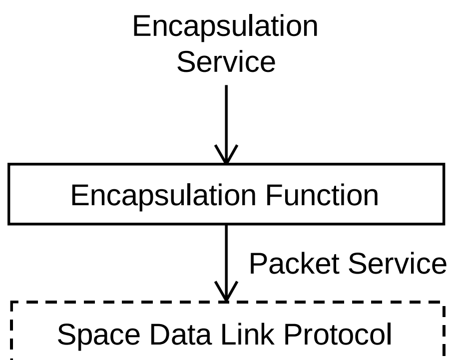


Figure 4-2: Internal Organization of Encapsulation Service (Sending End)

The Encapsulation Function (see figure 4-2) shall be used to encapsulate data units supplied by the service users. There is an instance of the Encapsulation Function for each packet structure used for encapsulation.

The Encapsulation Function receives data units from the service users. Any data unit that violates the limit of size shall be rejected. Each valid data unit shall be encapsulated in an Encapsulation Packet and passed to the Packet Service of the underlying Space Data Link Protocol.

4.9.4 PROCEDURES AT THE RECEIVING END

NOTE – This subsection describes procedures for providing the Encapsulation Service at the receiving end. (See figure 4-3.) The procedures described here are defined in an abstract sense and are not intended to imply any particular implementation approach of the service.

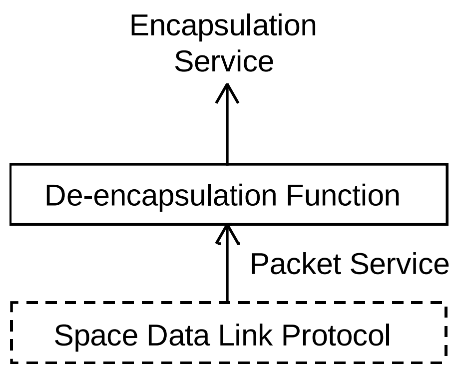


Figure 4-3: Internal Organization of Encapsulation Service (Receiving End)

The De-encapsulation Function shall be used to extract data units supplied by the service users. There is an instance of the De-encapsulation Function for each packet structure used for encapsulation.

The De-Encapsulation Function shall receive Encapsulation Packets from the Packet Service of the underlying Space Data Link Protocol and extract original data units by stripping the headers of the encapsulating packets. Extracted data units shall be delivered to the service user identified by Protocol ID.

ANNEX A

MANAGED PARAMETERS FOR CCSDS IP TRANSFER SERVICES

A1 GENERAL

Table A-1 lists the managed parameters associated with services associated with the CCSDS link layer protocols at the frame layer.

Table A-1: Virtual Channel Managed Parameters

Managed Parameter	TM	TC	AOS	Prox-1
Transfer Frame Version Number (binary value)	‘00’	‘00’	‘01’	‘10’
Spacecraft ID	Integer	Integer	Integer	Integer
VCID	0,1,…7	0,1,…7	0, 1, …, 63	Port_ID 0,1,…7

A2 MANAGED PARAMETERS FOR PACKET TRANSFER

Table A-2 lists the additional managed parameters associated with transferring packets over a VC.

Table A-2: Managed Parameters for Packet Transfer

Managed Parameter	Allowed Values
Valid Packet Version Numbers	Set of integers selected from table 7-6 of reference [8]
Maximum Packet Length (octets)	Integer
Whether incomplete Packets are required to be delivered to the user at the receiving end	Not required

A3 MANAGED PARAMETERS FOR ENCAPSULATION SERVICE

In order to conserve bandwidth on the space link, some parameters associated with the Encapsulation Service are handled by management, rather than by inline communications protocol. The managed parameters are those which tend to be static for long periods of time, and whose change generally signifies a major reconfiguration of the service provider associated with a particular mission. Through the use of a management system, management conveys the required information to the service provider.

The managed parameters used for the Encapsulation Service are listed in table A-3. These parameters are defined in an abstract sense, and are not intended to imply any particular implementation of a management system.

Table A-3: Managed Parameters for Encapsulation Service

Managed Parameter	Allowed Values
Minimum Data Unit Length (octets)	1
Maximum Data Unit Length (octets)	4,294,967,291
Valid Packet Version Number	Encapsulation Packet. For its value, see table 2-5, above.
Valid Protocol Identifiers (Used for Encapsulated Protocol ID, EPI)	See table 2-4, above.

ANNEX B

COMPREHENSIVE LIST OF SERVICE PRIMITIVES

Table B-1: CCSDS Packet Primitives

Data Link	Service Type	Service Primitive	Function	Semantics
AOS or TM	*VCP*	Request	Service user requests packet transfer.	PACKET.request(Packet, GVCID, PVN)
AOS or TM	*VCP*	Indication	Sent to the user when a Packet is ready to be delivered.	PACKET.indication(Packet, GVCID, PVN, Packet Quality Indicator (optional))
TC or Prox-1	*VCP*	Request	Service user requests packet transfer.	VCP.request(Packet, GVCID, PVN, SDU ID, Service Type)
TC or Prox-1	*VCP*	Indication	Sent to the user when a Packet is ready to be delivered.	VCP.indication(Packet, GVCID, PVN, SDU ID, Service Type, Notification Type)
TC or Prox-1	*VCP*	Notify Indication	Sent to notify the user of an event associated with the transfer of a Packet.	VCP_Notify.indication(GVCID, PVN, SDU ID, Service Type, Notification Type)
TC	*MAPP*	Request	Service user requests Map packet transfer.	MAPP.request(Packet, GVCID, MAP_ID, PVN, SDU ID, Service Type)
TC	MAPP	Notify indication	Sent to notify the user of an event associated with the transfer of a Packet.	MAPP_Notify_indication(GVCID, MAP_ID, PVN, SDU ID, Service Type, Notification Type)
TC	*MAPP*	Indication	Sent to the user when a Packet is ready to be delivered.	MAPP.indication(Packet, GVCID, PVN, SDU ID, Service Type (optional))
AOS, TM, TC, Prox-1	*Encapsulation Packet*	Request	Service user requests an Encapsulation Packet transfer.	ENCAPSULATION.request(data unit, GVCID, PVN, EPI)
AOS, TM, TC, Prox-1	*Encapsulation Packet*	Indication	Sent when an Encapsulation Packet is ready to be delivered to the user.	ENCAPSULATION.indication(data unit, GVCID, PVN, EPI, Data Unit Loss Flag (optional))

Table B-2: Octet Stream Primitives

Data Link	Service Type	Service Primitive	Function	Semantics
AOS or TM	*VCA*	Request	Service user requests a VCA_SDU transfer.	VCA.request(VCA_SDU, VCA Status Fields, GVCID)
AOS or TM	*VCA*	Indication	Sent to the user when a VCA_SDU is ready to be delivered.	VCA.indication(VCA_SDU, VCA Status Fields, GVCID, VCA_SDU Loss Flag (optional))
TC or Prox-1	*VCA*	Request	Service user requests a VCA_SDU transfer.	VCP.request(VCA_SDU, GVCID, SDU ID, Service Type (optional))
TC or Prox-1	*VCA*	Indication	Sent when a VCA_SDU is ready to be delivered to the user.	VCP.indication(VCA_SDU, GVCID, Service Type (optional))
TC or Prox-1	*VCA*	Notify Indication	Sent to notify the user of an event associated with the transfer of a VCA_SDU.	VCA_Notify.indication(GVCID, SDU ID, Service Type, Notification Type)
TC	*MAPA*	Request	Service user requests a MAP_SDU transfer.	MAPA.request(MAP_SDU, GVCID, MAP_ID, SDU_ID, Service type)
TC	*MAPA*	Indication	Sent when a MAP_SDU is ready to be delivered to the user.	MAPA.indication(MAP_SDU, GVCID, MAP_ID, Service type (optional))
TC	*MAPA*	Notify.indication	Sent to notify the user of an event associated with the transfer of a MAP_SDU.	MAPA_Notify.indication(GVCID, MAP_ID, SDU_ID, Service type, Notification type)

ANNEX C

NETWORK VIEWS

This annex contains example implementations corresponding to the list of options in 2.1 recommending how to transfer both IPv4 and IPv6 over CCSDS data links depending upon the routing capability and needs of the on-board network.

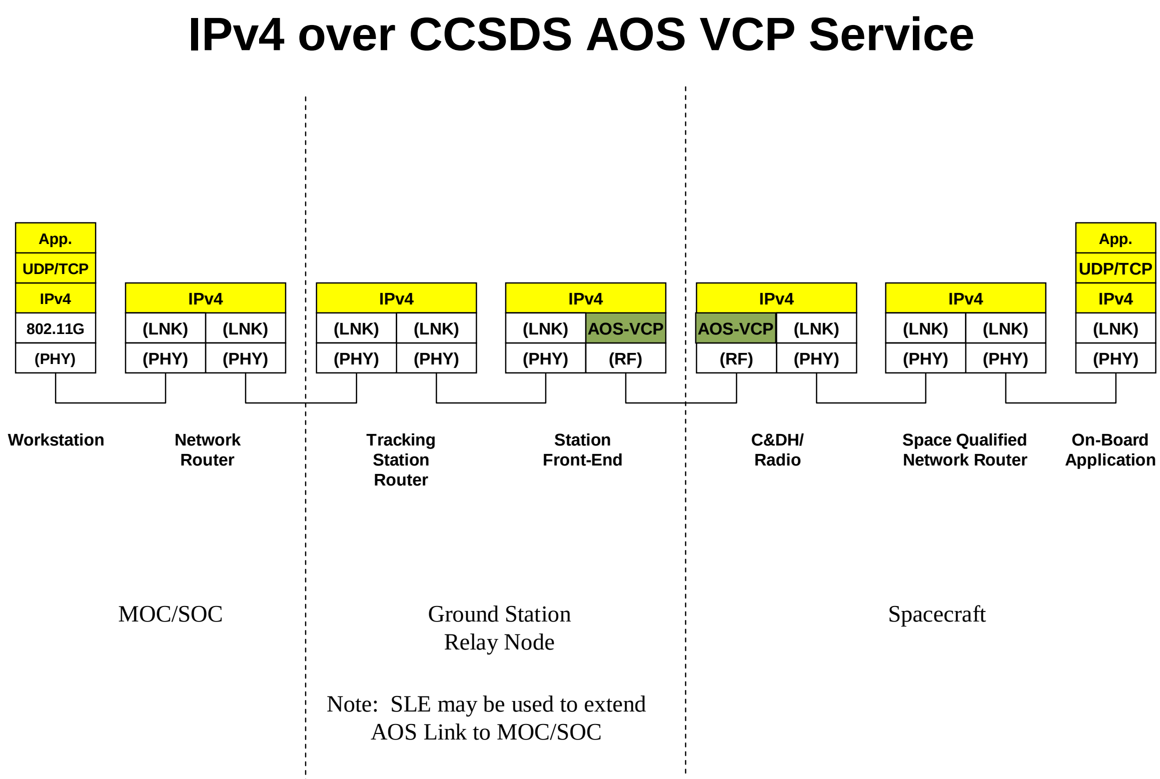


Figure C-1: Option 1a—IP over CCSDS AOS VCP Service

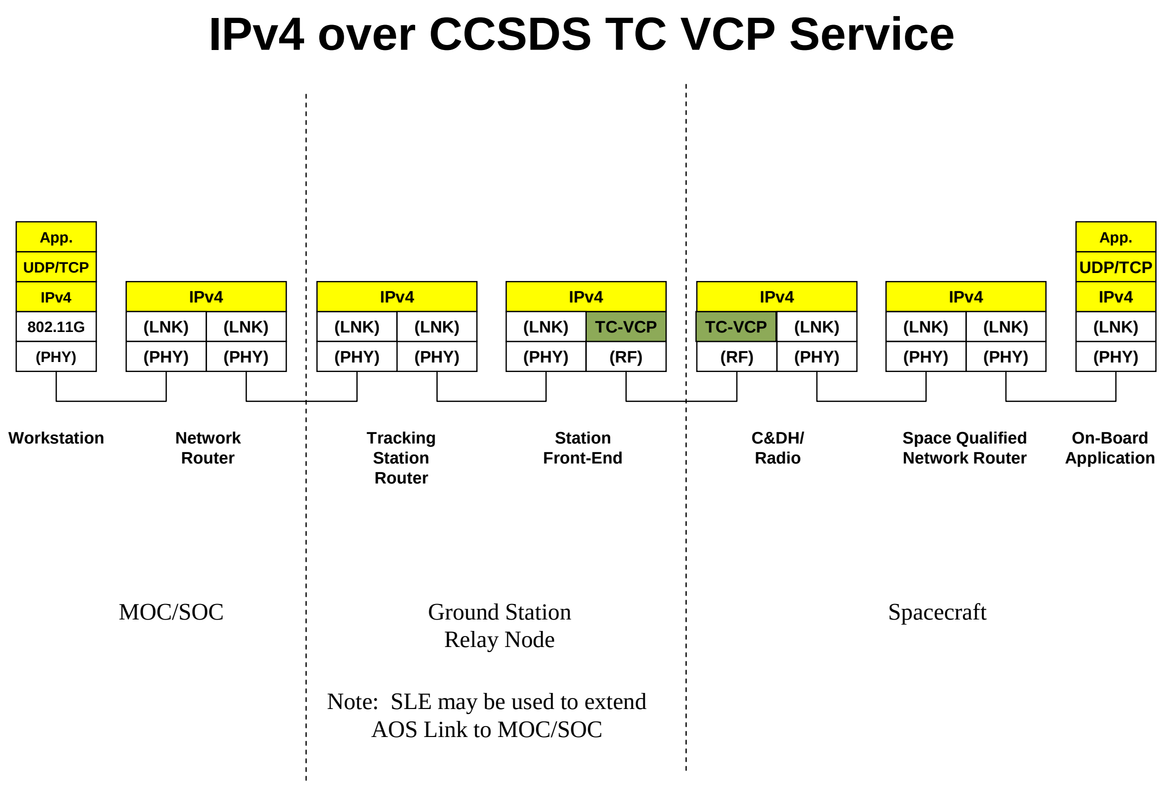


Figure C-2: Option 1b—IPv4 over CCSDS TC VCP Service

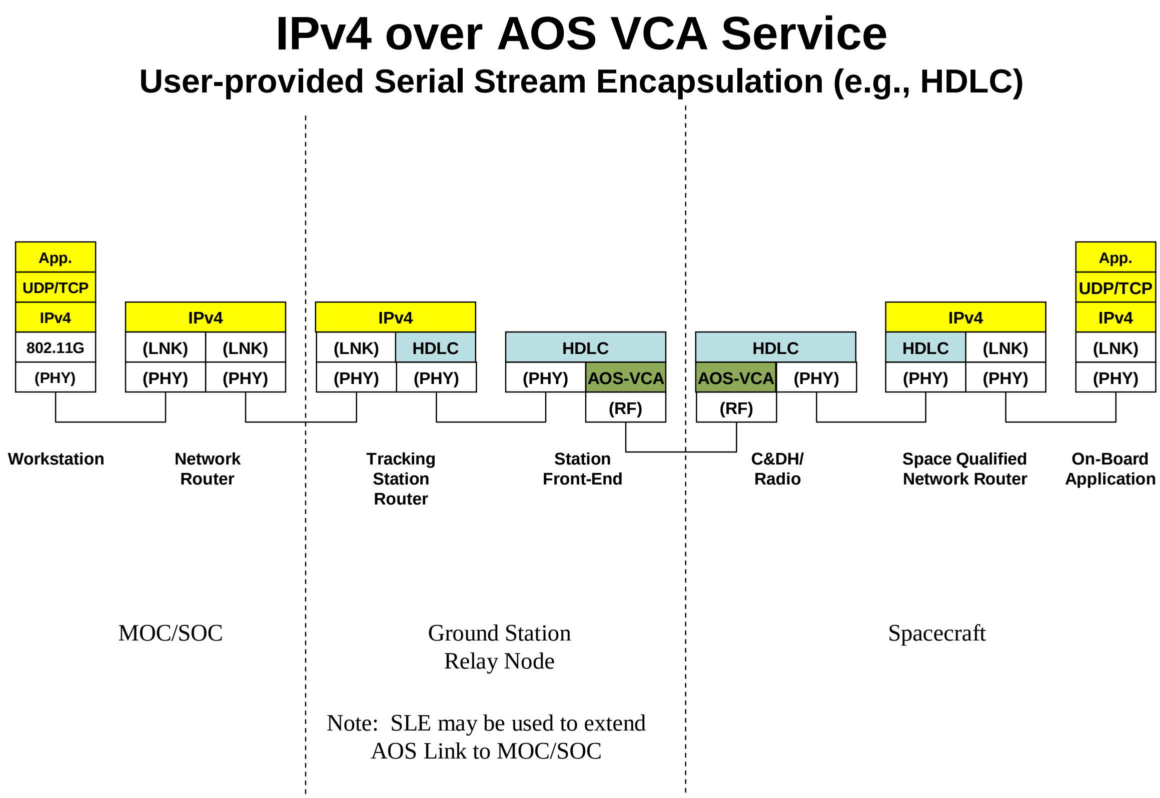


Figure C-3: Option 2—IPv4 over AOS VCA Service Using User-Provided Stream Encapsulation

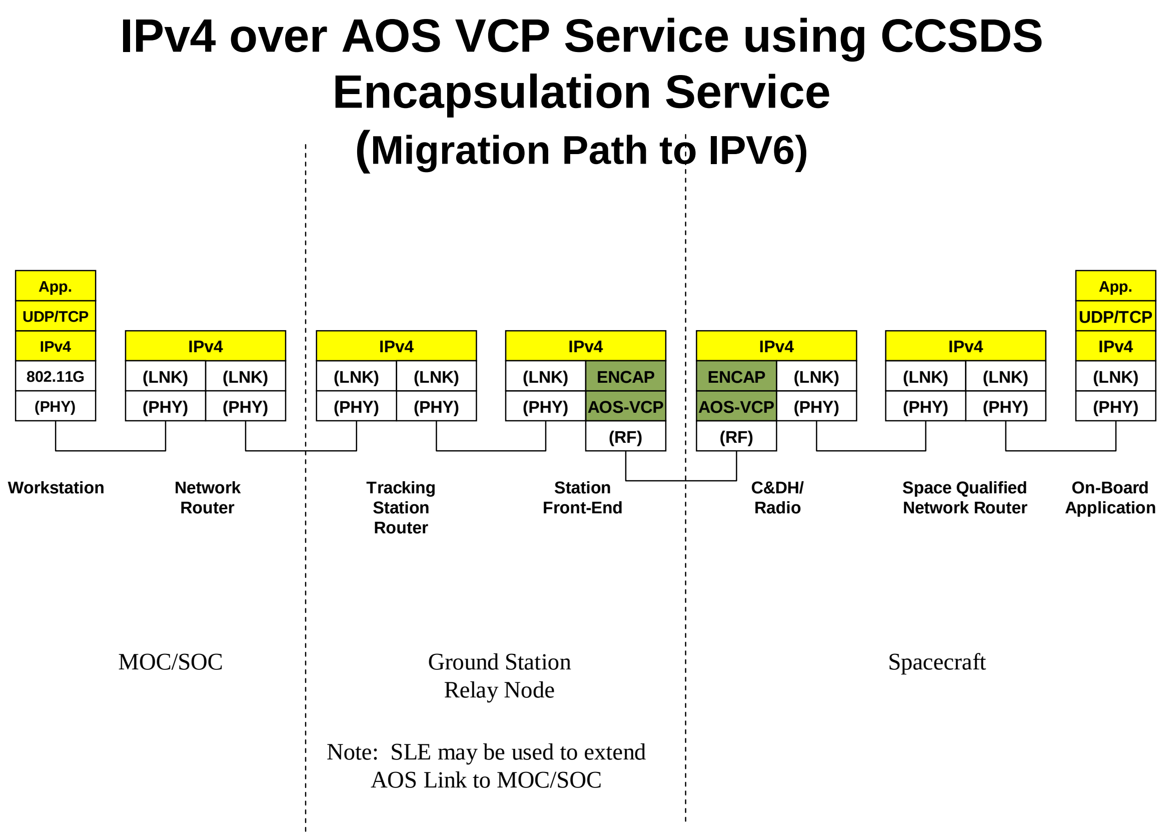


Figure C-4: Option 3—(Migration Path to IPv6) IPv4 over AOS VCP Service Using CCSDS Encapsulation Service

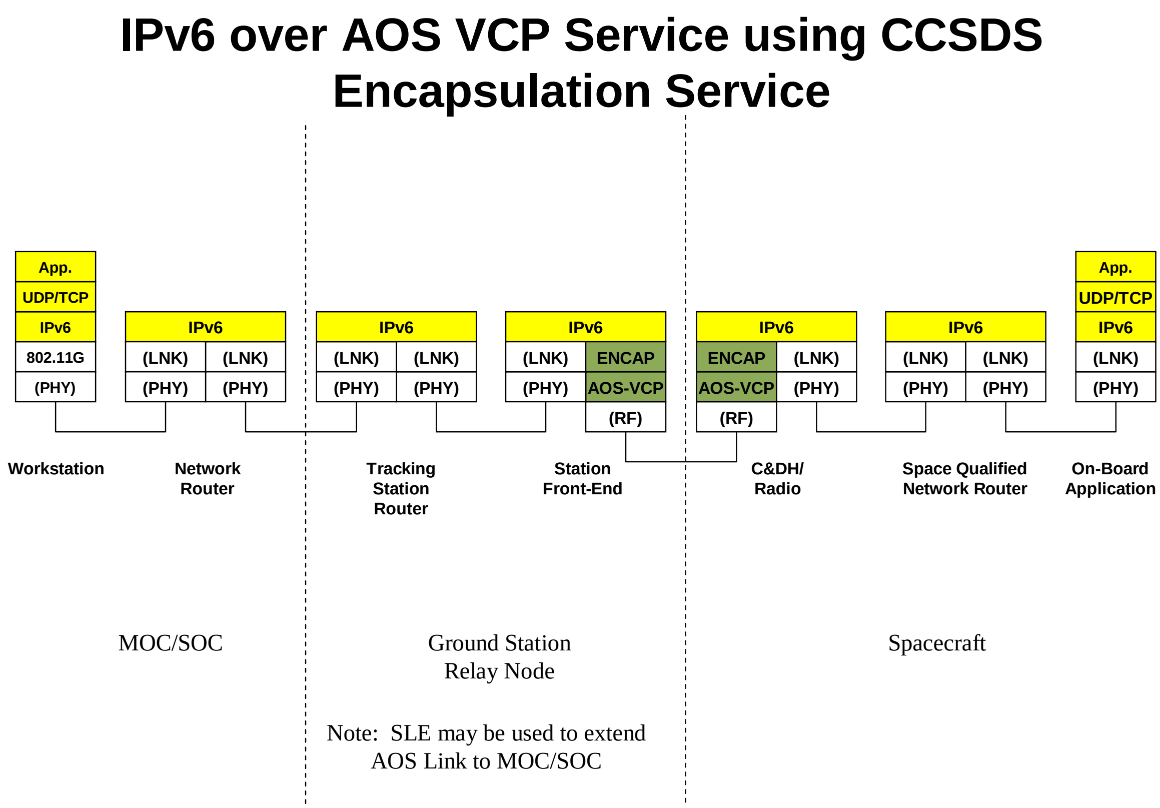


Figure C-5: Option 4—IPv6 over AOS VCP Service Using CCSDS Encapsulation Service

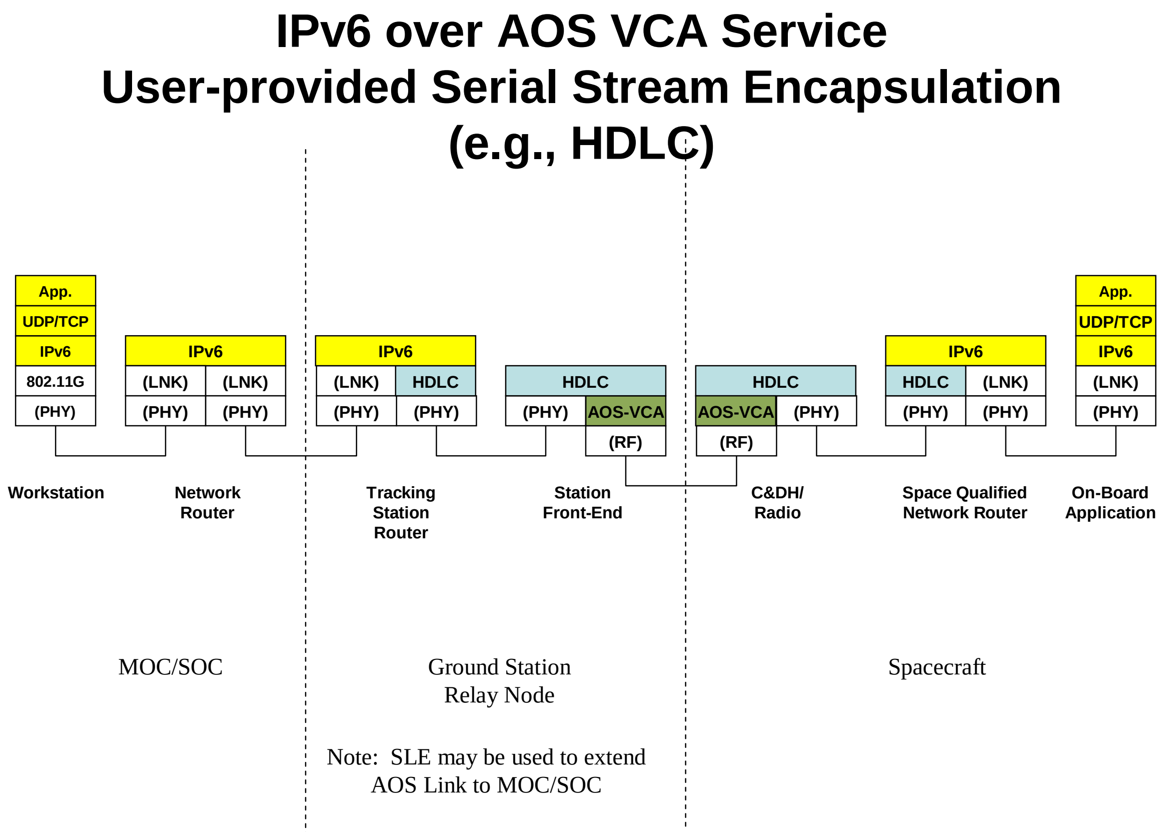


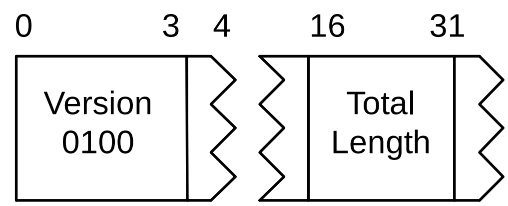
Figure C-6: Option 5—IPv4 over AOS VCA Service Using User-Provided Stream Encapsulation

ANNEX D

INTERPRETATION OF IPV4 PACKET VERSION NUMBER

This procedure applies to IPv4 datagrams transferred across the space link using either VCP or MAPP services.

NOTE – The complete definition of the IPv4 datagram is contained in reference [F7].



Internet Protocol v4 (IPv4) Datagram

On the receive side, the receiver checks the value of the packet version number. The first four bits of the IPv4 datagram are the version number. Reference [F7] defines these binary values as ‘0100’. For the purpose of transferring IPv4 datagrams over CCSDS Space Data Links, only the first three bits are checked; the fourth bit is ignored. If the first three bits of the packet are ‘010’, then the packet is an IPv4 datagram and is delimited by the length field, a 16-bit field starting at bit 16. The length field is a binary number corresponding to the total length of the IPv4 datagram (in octets). In each case, the location of the first bit of the packet is numbered ‘0’ (zero).

NOTE – Unlike the CCSDS Space Packet, the Length field is a binary number corresponding to the total length of the IPv4 datagram, including the header.

ANNEX E

LOCATION OF PACKET LENGTH FIELD

Table E-1 summarizes the location of the length field of Packets for which Packet Version Numbers are defined by CCSDS.

NOTE – This information is used by the Space Data Link Protocols (reference [3]-[5]) and Proximity-1 Space Link Protocol (reference [6]) to extract Packets from the Data Field of Transfer Frames.

Table E-1: Location of Packet Length Field

Version Number	Binary Encoded Version Number	Packet	Location of Length Field (See NOTE)	Interpretation of Length	Reference
1	000	Space Packet	32-47	Binary count of number of octets in Packet Data Field minus 1. Must add 7 to get full packet length.	[F10]
2	001	SCPS-NP	3-16	Binary count of total octets in Packet, including header. Shortest legal length is 4 (= 4 octets).	[F11]
3	010	IP version 4	16-31	Binary count of total octets in Packet, including header.	[F7]
8	111	Encapsulation Packet	8-15, 8-23, or 8-39	Binary count of total octets in Packet, including header.	[7]

NOTE – Counted in bits, from beginning of packet; first bit is numbered zero.

ANNEX F

INFORMATIVE REFERENCES

[F1] *Space Data Link Protocols—Summary of Concept and Rationale*. Draft Report Concerning Space Data System Standards, CCSDS 130.2-G-0.3. Draft Green Book. Issue 0.3. Washington, D.C.: CCSDS, July 2005.

[F2] *Telecommand Summary of Concept and Rationale*. Report Concerning Space Data System Standards, CCSDS 200.0-G-6. Green Book. Issue 6. Washington, D.C.: CCSDS, January 1987.

[F3] *Information Technology—Telecommunications and Information Exchange between Systems—High-Level Data Link Control (HDLC) Procedures*. International Standard, ISO/IEC 13239:2002. 3rd ed. Geneva: ISO, 2002.

[F4] W. Simpson. *PPP in Frame Relay*. RFC 1973. Reston, VA: ISOC, June 1996.

[F5] C. Brown and A. Malis. *Multiprotocol Interconnect over Frame Relay*. STD 55. Reston, VA: ISOC, September 1998.

[F6] P. Karn, Ed. *Advice for Internet Subnetwork Designers*. BCP 89. Reston, VA: ISOC, July 2004.

[F7] J. Postel. *Internet Protocol*. STD 5. Reston, VA: ISOC, September 1981.

[F8] S. Deering and R. Hinden. *Internet Protocol, Version 6 (IPv6) Specification*. RFC 2460. Reston, VA: ISOC, December 1998.

[F9] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. International Standard, ISO/IEC 7498-1. 2nd ed. Geneva: ISO, 1994.

[F10] *Space Packet Protocol*. Recommendation for Space Data System Standards, CCSDS 133.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.

[F11] *Space Communications Protocol Specification (SCPS)—Network Protocol (SCPS-NP)*. Recommendation for Space Data System Standards, CCSDS 713.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, May 1999.

[F12] *TM Synchronization and Channel Coding*. Recommendation for Space Data System Standards, CCSDS 131.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.

NOTE – Normative references are provided in 1.3.

ANNEX G

ACRONYM LIST

AOS	Advanced Orbiting Systems
ARQ	Automatic Repeat Request
CCSDS	Consultative Committee for Space Data System
ENCAP	Encapsulation (Packet Service)
ENCAP_SDU	Encapsulation Packet Service Data Unit
EPI	Encapsulated Protocol Identifier
GMAP ID	Global Multiplexer Access Point Identifier
GVCID	Global Virtual Channel Identifier
HDLC	High-level Data Link Control (protocol)
IP	Internet Protocol
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
MAP ID	Multiplexer Access Point Identifier
MAP_SDU	Multiplexer Access Point Service Data Unit
MAPA	MAP Access (Service)
MAPP	MAP Packet (Service)
MCID	Master Channel Identifier
MTU	Maximum Transmission Unit
OSI	Open Systems Interconnection
Prox-1	Proximity-1
PVN	Packet Version Number
RCF	Return Channel Frame Service (SLE Service)
RFC	Request for Comment

SAP	Service Access Point
SCID	Spacecraft Identifier
SDU	Service Data Unit
SLE	Space Link Extension
TC	Telecommand (pertains to TC Space Data Link Protocol)
TCP	Transmission Control Protocol
TFVN	Transfer Frame Version Number
TM	Telemetry (pertains to TM Space Data Link Protocol)
UDP	User Datagram Protocol
VC	Virtual Channel
VCID	Virtual Channel Identifier
VCA	Virtual Channel Access (Service)
VCA_SDU	Virtual Channel Access Service Data Unit
VCP	Virtual Channel Packet (Service)
VCID	Virtual Channel Identifier